中国科学院"八五"重大应用项目
——灾害性气候的预测及其对农业年景和水资源调配的影响

中国气候灾害的分布和变化

KY85-10-1

主　编：黄荣辉
副主编：郭其蕴　吴国雄

DISASTROUS CLIMATE

气象出版社

中国科学院"八五"重大应用项目
——灾害性气候的预测及其对农业年景和水资源调配的影响

中国气候灾害的分布和变化

KY85-10-1

主　编:黄荣辉
副主编:郭其蕴　吴国雄

气象出版社

(京)新登字 046 号

图书在版编目(CIP)数据

中国科学院"八五"重大应用项目:灾害性气候的预测及其对农业年景和水资源调配的影响/黄荣辉主编.一北京:气象出版社,1996.1
ISBN 7-5029-2065-X

Ⅰ.中… Ⅱ.黄… Ⅲ.①中国科学院-科学研究-计划-项目②灾害性天气-天气预报-影响-农业 Ⅳ.①G322.1②S165

中国版本图书馆 CIP 数据核字(95)第 18634 号

中国气候灾害的分布和变化

KY85-10-1

主　编:黄荣辉
副主编:郭其蕴　吴国雄
责任编辑:张　斌　　　终审:纪乃晋
封面设计:李如彬　　责任技编:张　斌　　责任校对:刘祥玉

*　　　*　　　*

气象出版社出版发行
(北京白石桥路 46 号　邮政编码:100081)
北京怀柔王史山印刷厂印刷

*　　　*　　　*

开本:787×1092　1/16　印张:19.5　　字数:500 千字
1996 年 1 月第一版　　1996 年 1 月第一次印刷
印数:1—600
ISBN 7-5029-2065-X/P·0776
定价:36.00 元

序

近十多年来，大范围的气候异常已给全世界许多国家造成了严重气候灾害。据统计，全世界每年因自然灾害造成的经济损失达600亿美元以上，其中约70%左右是天气气候灾害造成的。因此，气候变化的预测已成为当今科学界关心的重要科学问题之一，为此，许多国家还成立了气候预测中心，专门从事气候变化预测研究。我国是世界上气候脆弱区之一，并处于东亚季风区，气候异常经常发生，旱涝灾害频繁，每年造成巨大的经济损失。如1991年夏季江淮流域及长江中、下游发生了特大洪涝；1994年夏华南、辽南和华北北部发生了严重洪涝和江淮流域出现严重高温、干旱，造成约千亿元的经济损失。因此开展气候变化预测研究是一项具有巨大经济效益和社会效益的工作。

鉴于旱涝灾害的严重性及其开展气候预测研究的迫切性，中国科学院在"八五"期间开展了重大应用项目"灾害性气候预测及其对农业年景和水资源调配的影响"(编号:KY85-10)的研究，对我国主要的灾害性气候发生规律、成因、预测及其灾害的影响进行深入研究，以便为我国灾害性气候预测，特别是旱涝预测提供有物理基础、行之有效的预报模式。

项目下设五个课题：

第一课题：灾害气候状况及其发生、发展规律的研究；

第二课题：灾害性气候的形成过程及诊断研究；

第三课题：灾害性气候预测方法及预测试验研究；

第四课题：灾害性气候对农业年景和水资源调配影响的研究；

第五课题：面向灾害气候的资料应用系统。

本论文集是项目为总结研究成果而出版的论文集序列中有关气候灾害状况及其发生发展规律部分，即上述第一课题内容。它包括气候灾害和灾情；气候灾害的分布、类型；气候灾害的发生发展规律；历史气候灾害以及全球气候变化的影响等五个方面的内容。

本论文集目的在于促进气候预测有关研究以及与业务部门的交流。

中国科学院"八五"重大应用项目(编号:KY85-10)
——灾害性气候的预测及其对农业年景和水资源调配的影响
项目主持人：黄荣辉
1995年3月1日

Preface

During the recent ten years and more, the large-scale climate anomalies have caused severe climatic disasters in many countries in the world. According to statistical data, the global economic losses caused by natural disasters in the world were about more than 60 billion U. S. dollars in every year, among which 70% was due to weather and climate disasters. Therefore, the predictions of climate variabilities have become one of the important scientific problems which are attracting scientific field's attention now. For the sake of climate prediction, the centers for climate prediction are established in many countries, which focus on the studies on the prediction of climate variabilities. Our country is one of the vulnerable climate regions and is in the East Asian monsoon area, therefore, the climate anomalies often occur, and drought and flood disasters are frequently caused there. These disasters bring huge economic losses in every year. For example, the particular severe flood occurred in the Huaihe River basin and middle and lower reaches of the Yangtze River in the summer of 1991, the severe flood occurred in South China, the southern part of Liaoning Province and the northern part of North China and the hot and severe drought occurred in the Yangtze River basin and the Huaihe River basin in the summer of 1994 which caused the economic losses of about 100 billion RMB and more. Therefore, the study on the prediction of climate variabilities is a huge beneficial work for both society and economy.

Due to the severity of drought and flood disasters and the urgency of developing the study on climate prediction, Chinese Academy of Sciences carries out a key application research project "The prediction of disastrous climate and its impact on agriculture and management of water resources" (No. KY 85-10) during the period of the 8th five-year plan. This project focuses on the deep study on the regularity, cause and prediction of the main disastrous climate occurring in China and its impact on agriculture and management of water resources, so that an efficient prediction model with physical bases can be proposed for the prediction of the disastrous climate, particularly drought and flood occurring in China.

There are five following research topics in this project:

Research topic 1: Study on the observational facts of disastrous climate and the regularity of its occurrence and development.

Research topic 2: Study on the formation processes of disastrous climate and its diagnostics

Research topic 3: Study on the prediction method and prediction experiments of disastrous climate

Research topic 4: Study on the impact of disastrous climate on agriculture and water resources

Research topic 5: Study on an application system of the observed data base for disastrous climate.

The collected papers are the part associated with the observational facts of disastrous climate and the regularity of its occurrence in the series of the collected papers published for the summaries of investigated results of this project, i. e. , the content of the first research topic mentioned above. Five aspects of the results studied on the disastrous climate and the facts of damage, the distributions and patterns of disastrous climate, the regularity of the occurrence and development of the disastrous climate occurring in China, the historical climate disasters and the effect of global climate change on the disastrous climate, are included in the collected papers.

The object of the collected papers is to promote the exchange between institutes associated with climate prediction and operational divisions of climate prediction. Since the time for writing these papers is short, there are maybe some errors in the collected papers. Therefore, any valuable comments or suggestions for the collected papers are welcome.

Prof. HUANG Ronghui
Chief Scientist of the Project "KY85-10",
the Key Applied Project of Chinese Academy of Sciences
during the 8th Five-Year-Plan

前　言

本文集是中国科学院"八五"重大应用项目"灾害性气候的预测及其对农业年景和水资源调配的影响"(编号:KY85-10)中第一课题的部分研究成果汇编。第一课题研究"气候灾害情况及其发生发展规律",课题下设五个专题:

1. **各种时间尺度(主要是季度、年际)的灾害性气候所造成的灾害情况;**
2. **我国不同地区气候灾害的分布、类型和发生频率的统计研究;**
3. **我国不同地区灾害性气候发生规律及发展趋势;**
4. **近代气候灾害与历史气候灾害的关系;**
5. **我国气候异常和全球气候变化的关系。**

文集共收入有关论文35篇,大体按五个专题的顺序排列。

关于气候灾害和灾情,这里需要说明的是本课题研究的主要是能够造成灾害的气候异常,或者说,重点是研究异常气候而不是灾情。但是为了对什么样的气候异常可能造成灾害,以及多大的气候异常可能造成多少灾害有一个基本概念,个别专题也分析了气候灾害对农业生产所造成的影响。不过这是个很困难的问题,因为粮食产量并不完全决定于气候条件,还受耕作技术、社会变革等多种因素的影响。因此通常用消去趋势的办法,并不一定完全能找到所谓气象产量变化,即完全决定于气象条件的产量变化。另外,产量变化也不只决定于一种气候要素,而经常是受不同时期多种气候要素的影响,并且大部分还不是线性关系。所以,要找到某一种气候要素完全决定某一种作物的产量几乎是不可能的。但是如果从气候角度来衡量,一定的气候异常会造成农业灾害,则多数情况下还是肯定的。例如研究表明,东北地区5—9月气温比多年平均低1℃时,可使水稻减产46.5公斤/亩;长江中下游4—10月降水量多100mm,水稻减产7.5公斤/亩。又如北京1968年因前一年初霜早14天,当年终霜又迟27天,使小麦减产40—50公斤/亩。这些例子都说明气候灾害影响的程度。有时把几种气候灾害组合建立综合影响指数与产量变化的关系则更好一些。

但是必须正确理解气候变化和农业产量的关系。例如低温减产,高温可能对作物有利,但不一定就有同样数量的增产,也就是说,两者并不能一一对应,更何况农作物的受灾程度还同生产条件、农业技术措施以及作物品种等诸多因素都有密切关系。因此,本课题着重从气候角度而不是从农业角度来研究气候灾害。

虽然气候灾害是一个比较复杂的问题,但是经过多年来的研究,对于对作物的生长造成较大危害的那些异常气候,尽管还缺少比较系统的分析,但已有了初步认识。为了深入研究气候灾害及其规律性,本课题利用1951—1990年完整的资料,对影响我国的旱、涝、低温、寒害、霜冻、雪灾、台风等7种灾害做了系统的分析,作出这40年逐年每个季的气候灾害分布图(图集将另行出版),同时对这7种灾害也做了一定程度的总结,大部分结果已收入本文集中。

干旱和雨涝是对我国农业生产影响最大的两种气候灾害。根据对1978年到1989年的统计,旱灾占全国自然灾害影响面积的60%,涝灾占23%。这就是说有80%以上的自然灾害是旱涝造成的,其中干旱影响尤为巨大。但关于旱、涝的定义,到目前为止尚未取得共识,就更谈不上有一个大家都认可的旱或涝的标准了。但大家都承认,干旱是长期缺少自然降水的结果,而自然降水过多则又是引起洪涝的直接原因。因此我们仍以降水量为基础,对不同季节、不同

地区采用不同的降水距平百分率来划分旱和涝，研究了其地理分布、发生频率及形成过程。人们过去对夏季江淮流域的旱涝研究较多，实际上，其它地区、其它季节的旱涝影响也不容忽视。所以对西北、西南、华北以及华南等地区的旱涝都作了专门分析，同时对夏季黄河流域强降水与汛期降水的时空变化也做了研究。关于夏季的旱涝情况，概括地讲，60 年代到 70 年代初是全国干旱时期，80 年代则是长江流域多雨期。

对春季与秋季的旱涝分析表明，春季干旱在我国东北及华北最突出，其次为西南地区，从时间变化来看，60 年代是干旱集中发生的时期；秋季旱和涝均易发生，但秋涝主要集中在我国东部及南部，秋旱则分布较广，全国大部分地区均可发生，从时间变化看，60 年代也是各种类型秋旱比较集中的时期。

从气候角度研究旱涝主要是分析降水量多少，但同期的温度也有很大影响，因此还分析了反映农业需水满足程度的指数。结果表明，华北地区自然降水只能满足农业需水量的 50—70%。因此，华北干旱是一个普遍的现象，其中以春旱最重，秋旱次之，夏旱也时有发生。这种分析比单纯考虑降水变化更适合农业生产的需要，因此与粮食产量的关系也较密切。

低温也是对我国农业生产有重要影响的气候灾害。在本文集中主要分析了华南的春季低温冷害、秋季寒露风、冬季寒潮，以及江淮流域的初终霜冻和东北的夏季低温。春季华南有时遭受连续 3 天以上 12℃以下的低温，这种低温过程对早稻播种有非常大的影响。如 1976 年由于低温早稻烂秧，仅广东、广西和福建 3 省区就损失稻种 1.7 亿公斤。这种低温灾害有 3—4 年周期及准 20 年周期的年代际变化，即 60 年代和 80 年代低温频率高。秋季寒露风主要影响华南的晚稻生产。近 40 年中 9 次寒露风有 7 次发生在 60 年代后期到 70 年代，表现出明显的年代际变化。冬季影响华南的寒潮，降温可达 10—19℃，不仅影响越冬作物与多年生的经济林木，而且对交通、通讯及输电等均有很大影响。40 年中 9 个寒潮均发生在 60—70 年代，但包括强及弱寒潮的频率 50 年代最高，80 年代最低，似乎有一定的减弱趋势。

江淮地区则受初霜冻影响较大。以 5% 及 11% 概率作为判断特早(特晚)及早(晚)初(终)霜日期的标准。分析表明，初终霜日期有 2—3 年周期，年代际变化不甚明显。长江流域终霜日在 60 年代及 80 年代较迟，淮河流域终霜日有提前的趋势。我国其它地区也受初终霜冻日期变化的影响，如 1953 年终霜日推迟 10—20 天，河北省小麦减产 5 千万公斤以上。

夏季低温对全国许多地区的农业均有影响，但以东北地区最为显著。在东北严重低温冷害年，5—9 月平均气温可低于常年 1.7—4.4℃，黑龙江、吉林、辽宁 3 省粮食分别减产 30%以上、30%和 20%，可见影响之巨大。分析表明，低温年特别是严重低温年经常发生在厄尔尼诺年；从年代际来看，50 年代与 70 年代冷害较重，80 年代较轻。

冬季雪灾对我国新疆、青藏高原及内蒙古 3 大牧区的畜牧业影响很大。如 1989 年 2—4 月青海降雪达 30 多天，造成 160 多万头成畜及 96 万头仔畜死亡，经济损失 1.7 亿多元。1961—1990 年 30 年间，3 个牧场雪灾频率分别为 23%、16%及 6%。前两个地区从 60 年代到 80 年代雪灾有增加趋势，与冬季气温的上升有一定关系。

台风也是一个重要的气候灾害。1949—1992 年西北太平洋平均每年出现台风 28 个，但最多可达 40 个(1967 年)，最少 20 个(1951 年)，相差 1 倍。登陆我国的台风每年平均为 7 个，最多 12 个(1971 年)，最少 3 个(1950 年，1951 年)，相差也在 1 倍以上。1983—1992 年因台风影响而造成的损失平均每年为 31.5 亿元。台风与 ENSO 有关，多数厄尔尼诺年台风出现正常偏少，反厄尔尼诺年偏多。

综上所述，从最近 40 年的情况来看，我国气候灾害有三种变化规律，一种是 2—3 年或 3

—4 年的短周期变化，其中 3—4 年的变化可能与 ENSO 有关；一种是年代际变化，干旱、低温冷害多出现在 60—70 年代，这与我国同期气候偏冷的总趋势有关；第三种是趋势性变化，这可能与冬季气候的变暖有关。

此外，不同的气候灾害有时是同时发生的，这无疑会加重其对经济和社会的影响。因此对各种灾害在各季的组合也进行了研究。

由于我国的气候受季风影响显著，气候灾害与夏季风的异常有密切关系。为了深入了解旱涝灾害的机制，对季风降水的时空分布进行了专门分析。把我国 110°E 以东地区，从南到北分作 13 个纬度带，研究了各纬度带 3—10 月月降水量的年际变化。EOF 分析表明，月降水量正常季节进程的方差贡献达到 86.5%，其时间系数变化表明多雨年与少雨年的总降水量可差 50%。其它高阶 EOF 或者反映旱涝的南北差异，或者反映雨季来临早晚的不同。EOF_1 的时间系数有 2.8 年和 22.0 年两种周期，反映了我国东部月降水季节进程的主要变化规律。以雨量最多的华南地区为代表，50 年代和 70 年代多雨，60 年代和 80 年代少雨。

在揭示降水空间分布的特征方面，方差极大正交转动 EOF 分析方法有一定优点。对我国夏季(6—8 月)降水量的分析表明，$REOF_1$ 占总方差 12.4%，表现为长江中、下游与华北地区有明显反相关；$REOF_2$ 占总方差 11.4%，表现为青藏高原东部降水与东北一致，长江下游以南地区与我国西北一致。过去人们还较少注意到这种空间分布特征。由此分析了我国各区降水异常之间的关系，并研究了西太平洋副热带高压及青藏高原环流指数与降水异常的关系。对时间系数分析发现有 2—3 年和 10 年左右的周期。对中国及日本夏季降水的 EOF 及 REOF 分析表明，我国江淮流域与日本西部同属一个气候系统。60 年代末及 80 年代初东北降水突变最明显，还发现我国大部分地区夏季降水有 2.5 年周期。以上分析表明，我国降水有明显的高频变化，并且可能与 ENSO 有一定关系。CEOF 分析也表明，ENSO 可能对我国夏季降水有影响：从 1953、1957 和 1965 年看，厄尔尼诺当年及后一年长江以南及华南 6 月多雨、7—8 月少雨，长江以北相反，6 月少雨、7—8 月多雨。厄尔尼诺前一年江南多雨，淮河流域则少雨。分析全球海温与江淮流域 6 月降水，发现也有一定联系。此外，研究还发现，冬季风的变化对我国夏季旱涝变化有指示性，这个关系对旱涝预测有一定意义。

以上谈到的主要是分析近 40 年气候资料所得到的结果。我国有丰富的史料，对历史时期的旱涝也进行了研究，分析结果可作为近代旱涝规律的佐证，并有助于认识当前这 40 多年旱涝变化所处的气候背景。过去研究历史旱涝多指单站，本课题建立了长江流域、黄河流域、海河流域近 500 旱涝序列，并且对长江中游与下游、长江流域与黄河流域作了比较。分析表明，长江下游大旱大涝均约 30 年一遇，但 20 世纪出现大涝 7 次，其中 6 次发生于下半世纪，这说明近 40 多年是长江流域大涝的频发期。但黄河流域 20 世纪旱涝频率不高，大旱大涝的频发期在 17—18 世纪。海河流域 20 世纪大旱频率也较高。我国旱涝周期变化主要集中在 3 个频率带：准两年、5 年左右及 20 年左右。海河流域及长江中游、黄河上游两年周期突出，长江中、下游均有 5 年左右及 20 年左右的周期，黄河下游也有 5 年周期，黄河中游则有 20 年左右周期。这些结果支持了根据降水量变化所得到的旱涝变化周期性的研究。此外，还注意到，从历史时期看我国气候以暖干和冷湿型为主，但黄河流域暖干占优势，长江流域则冷湿占主要。不过这个问题比较复杂，尤其降水与全球气候变暖关系更为复杂。从目前的分析来看，全球变暖可能促使印度夏季风加强，降水增加。但我国、尤其南方降水变化与之不同。因此还要继续作大量工作，才能得出更为确切的结论。

总之，我国的气候灾害是一个非常复杂的课题，且关系到农业、气候、水文等各个方面。在

数年内完全搞清楚是不可能的，也不符合科学发展的实际情况。本课题只是在现有资料及科学基础上，力争对这方面的问题作了一些较为系统的分析。不少问题还需要进一步深入研究。

本文集由中国科学院地理研究所郭其蕴、大气物理研究所吴国雄和国家气候中心孙安健负责编审工作。

中国科学院"八五"重大应用项目（编号：KY85-10）
——灾害性气候的预测及其对农业年景和水资源调配的影响
第一课题组长：郭其蕴
1995 年 3 月 8 日

Foreword

The topic "Study on the observational facts of disastrous climate and the regularity of its occurrence and development" is the 1st research task of the key application research project "The prediction of disastrous climate and its impact on agriculture and management of water resource" (No. KY 85-10) supported by Chinese Academy of Sciences during 1991—1995. It includes following five sub-tasks:

1. disasters caused by different time scale mainly seasonal and annual disastrous climate;

2. statistical research of spatial distribution, type and frequency of occurrence of climatic disasters;

3. occurrence rule and development trend of climatic disasters;

4. comparison of disastrous climate at present time to that in historical time;

5. relationship between climatic anomalies over China and over the globe.

Altogether 35 papers appeared in the collected papers, which were arranged in order of the number of sub-tasks.

Concerning the damages of climatic disasters, it should be noted that studies of the first topic had concentrated on climatic anomalies and changes which usually bring about damages to the agriculture and water resources, rather than on the damages themselves. However, a fundamental knowledge of latter is necessary for completeness of the topic, and for understanding and awaring the severity of disasters. It will provide a quantitative idea about the damage, especially, to the crop yields. Unfortunately, it does not mean a simple job, for crop yield depends not only on the climatic conditions, but also on the progress in technology and on the reforming of the society. Therefore, the impacts of factors other than climate need to be removed by subtracting the trend from original crop yield series. Nevertheless, a linear or polynomial trend will not always depict the non-climatic impact. The procedure itself sometimes eliminate a part of the variance which relates to changes of climatic conditions, and some of the impact of the society were still remained in the series. Moreover, the relationship between the crop yield and climatic conditions has never been linear in character, so it is very difficult to find any straightforward dependence of crop yield on a single climatic factor. Therefore, the crop yield was often compared with a disaster index which consists of several climatic factors. The discussion outlined above, however, does not imply the impossibility of finding out a predominant disaster to any one kind of the crop yields. Studies of this topic indicted that 1℃ of lowering in temperatures averaged from May to September will reduce the rice yield in 46.5 kg/mu (1ha=15mu) in Northeast China, and 100mm of increasing in April—October rainfall will decrease the rice yield by 7.5 kg/mu in Changjiang River Valley. Delay of the last frost or earlier arrival of the first frost are unfavorable for wheat yield in North China. For example, in 1968 in Beijing the first frost appeared 14 days earlier than normal and the last frost occurred 20 days later than normal, while wheat yield decreased by 40—50 kg/mu.

However, these relationship may or may not true in the reversed situations. Of course, high temperature is in favor of the rice yield in Northeast China, but an 1℃ positive anomaly of temperature does not necessary imply 46.5 kg/mu of increasing in rice yield. Variations in crop yield depend to a great extent on cultivating technique, species of the crop and social environment. That is also the main reason why we concentrated on the climate rather than on the damages.

Despite the great complexity of the relationship between the climatic conditions and crop yield, studies in this field has already identified a great deal of climatic disasters which are crucial to agriculture in China. A systematic study based on the data set from 1951 to 1990 has been carried out in the present topic to reveal the most serious climatic disasters to agriculture. A series of climatic disaster map has been compiled for each season for the forty years and will be published. Results of the analysis on the seven climatic disaster, i. e., drought, flood, low-temperature, cold wave, frost, snow disaster and typhoon are included in the present collected papers.

Droughts and floods are the disasters which have the greatest impact on crop yield in China. Studies show that 60% of the agricultural damage are related to droughts, and 23% to floods. This is to say that more than 80% of the natural disasters in crop yield are due to drought and flood. However, climatologists, agriculturists, and hydrologists use different definitions for drought and flood. In this collected papers the percentage rainfall anomaly is used to define the phenomena, for the natural rainfall is the fundamental factor which results in the occurrence of drought and flood. Different thresholds were adopted to fit the seasonal and geographical changes in precipitation. Studies in this field have been concentrated greatly on summer droughts or floods along the Changjiang-Huaihe River Valley for the greater destructiveness than the others. The droughts in 1960's and the floods in 1980's are well know in China. However, droughts and floods in other seasons and other places are also important to the agriculture in China. Therefore, droughts and flood in spring and autumn were also examined in detail. It is indicated that spring drought was prominent in North China, but also can be found in Southwest China. Most of spring drought occurred in 1960's. Autumn flood has great frequency in East and South China, but autumn drought is very common in the whole China. 1960's is also the decade in which a lot of autumn droughts occurred.

Temperature changes were also considered in studying the impact of drought and flood, because water requirement of agriculture depends also on temperature. An index was designed to represent this requirement. Studies indicated a deficit of 30—50% of the water amount needed for the agriculture in North China, especially in spring and autumn, but sometimes also in summer.

Generally, lowering of temperature influences negatively on the crop yield. Cold disaster in spring and autumn, and cold wave in winter in South China, frost disaster in Changjiang River Valley, and summer low temperature disaster in Northeast China were examined.

In spring persistence of daily temperature lower than 12℃ will destroy the sowing of rice. For example, in 1976 in South China 1.7×10^5 tons of rice seeds were lost due to the spring low temperature. These spring cold disasters occurred with a 3—4 year cycle and a ten-year alternation. The frequency of spring cold disasters was higher in 1960's and 1980's than other decades. Autumn cold disaster, locally referred as Cold Dew wind, will damage the late rice yield in South China. Seven of the nine cold disaster events in the last 40 years occurred in the period of late 1960's and 1970's, showing obvious inter-decadal variability. Severe cold wave which can lower the process temperature by 10—19℃ within a few days influences not only on the overwinter crop and multi-year growth economical forest, but also on transportation, communication and power transmission. Nine severe cold wave event during the last 40 years all appeared in 1960's and 1970's, although the frequency of weak cold wave was higher in 1950's than in other decades. 1980's was characterized with diminishing of cold disasters, in spite of that positive temperature anomaly of 1980's in China was much less than that for the globe.

Extremely early (extremely late) or early (late) first (last) frost along the Changjiang-Huaihe River Valley have occurred with the probability of 5% and 11% respectively. A 2—3 year cycle was found in the former and decadal alternation was not significant. The last frost came late in 1960's and 1980's along the Changjiang River Valley. But the variation of the date of last frost along Huaihe River Valley showed some trend of its early ending. Changing of dates of first and last frost in North China can also damage the crop yield, for example, delaying of 10—20 days of last frost in 1953 reduced the wheat yield in about 50 million kg in Hebei Province.

Low-temperature is one of the serious disasters in summer. It will damage crop yield especially in Northeast China. A severe low-temperature season (May to September) with temperatures usually 1.7—4.4℃ lower than the normal can reduce crop yields in Heilongjiang, Jilin and Liaoning Provinces by more than 30%, 30% and 20%, respectively. Most of the cold summer in Northeast was stronger in 1950's and 1970's than in the other decades.

Heavy snowing in Xinjiang Autonomous Region, Tibetan Plateau and Inner Mongolia Autonomous Region influences greatly on animal husbandry. A prolonged snowing lasting for 30 days from February to April of 1989 perished about 1.6 million of animals and 0.96 million of young animals. It costs about 170 million yuan. Snowing disasters during 1961—1990 occurred with the frequency of 23%, 16% and 6% respectively in the aforementioned three regions. An increasing trend was found from 1960's to 1980's in the first two regions. It is believed to be related to the general warming trend in winter.

Typhoon is another series disaster, which affects not only on agriculture but also on society. 28 typhoons per year were observed in western Pacific in average for the period of 1949—1992, with maximum of 40 (in 1967) and minimum of 20 (in 1951). The number of landing typhoon varied between 3 (in 1950, 1951) and 12 (in 1971). The average was 7 for the same period. This frequency decreased in an El Nino year and increased in a La Nina year.

Studies mentioned above indicated that climatic disasters in China vary with three time scale fluctuations: (1) short term climatic oscillation such as 3—4 year cycle which may be linked with ENSO; (2) decadal variability, most of the disasters were concentrated in 1960's—1970's, it may be related to the coldness during that time in China; and (3) the long term climate variation trend, it may be associated with the warming of the climate.

Of course, some disasters can be found in the same season or the same years. It will undoubtedly aggravate the damage to the economy and society. Then, the combination of the disasters was also examined.

China is one of the countries in which monsoon dominates the climate over the territory, so climatic disasters are closely related to monsoon variability. To understand the mechanism of climatic disasters, variability of monsoon rainfall was studies in detail. EOF analysis was carried out for the rainfall field which consists of latitudinal average from 20—45°N and from March to October, EOF_1 showed that the normal seasonal course explains 86.5% of the total variance. Changes in temporal coefficient indicated a 50% range of the total rainfall from a dry to a wet year. The high order EOF showed contrast between the months or between the latitude zones. Power spectrum analysis of EOF_1 coefficient depicts a definite peak in 2.8 year and 22 year band. The latter reflects the rainfall deficit in South China in 1960's and 1980's.

The technique of rotated EOF (REOF) has some advantages in revealing the spatial character of rainfall anomaly. $REOF_1$ of summer (June—August) rainfall anomalies explains 12.4% of the total variance, it shows obvious contrast between the lower and middle reaches of Changjiang River and North China. $REOF_2$ is characterized with the contrast between the eastern Tibetan Plateau and Northeast China in one hand, and Southeast and Northwest China in the other, which explained 11.4% of the total variance. The latter has never been found in other previous studies. Moreover, relationship of REOF coefficient to the subtropical High in western Pacific and to the Tibetan Plateau circulation index was examined. Power spectrum analysis of rainfall variations showed the existence of 2—3 year and 10 year cycle. EOF and REOF analysis of summer rainfall in China and Japan indicted that the Changjiang-Huaihe River Valley and west Japan are under the control of a common climate system. Abrupt change in rainfall variations in Northeast China was significant by the end of 1960's and in the early 1980's. The 2.5 year cycle and other high frequency fluctuations of rainfall infers the possibility of its linkage to the ENSO. CEOF analysis also supported the association to ENSO. In 1953, 1957 and 1965 (all are referred as El Nino year) and the following years, rainfall was above normal in June and below normal in July and August in South China, but it was below normal in June and above normal in July and August in North China. Rainfall was above normal in South China and below normal along Huaihe River in the year before an El Nino year. Some relationship of June rainfall to the SST in global scale was found. Studies also indicated that winter monsoon can be used as an predictor of summer rainfall. All these may be considered in making seasonal rainfall prediction.

The results outlined above were based on observational data set for the last 40 years. In China there exist a lot of documentary data. The historical data about drought and flood provide good evidence of the periodicity which was found from observational data, and supply important background information for modern climate. Many early studies on drought and flood are based on the data for single stations. The present subject has carried out a series of research to construct drought and flood series for Changjiang, Huanghe and Haihe River Valleys and for their reaches from 1470 to 1990 AD. Then the occurrence of drought or flood in one of the reaches was compared with those in other reaches. This provides some spatial pattern of drought and flood over China. Changes of frequency of severe drought and flood are evident. Seven severe flood events were found in 20th century, along lower reaches of the Changjiang River Valley, and among them six occurred in the second half of the century, though the mean frequency is once in thirty years in the period of last five centuries. It infers that the recent forty year period is characterized with greater frequency of severe flood along the Changjiang River Valley. Much more frequent severe drought and flood along the Huanghe River Valley appeared in 17—18th century rather than in 20th century. But the frequency of severe drought and flood in the Haihe River Valley was greater than normal in the 20th century. Historical documents proved that fluctuations of drought and flood are concentrated in three frequency bands: Quasi-Biennial, 5 year and 20 year cycle. The QBO predominated over middle reaches of Changjiang River, the upper reaches of Huanghe River and Haihe River. The 5 year cycle is prominent in the area of middle and lower reaches of Changjiang River and lower reaches of Huanghe River. The 20 year cycle is found in the middle and lower reaches of the Changjiang River and middle reaches of the Huanghe River. These results are more or less consistent with those identified from the observational data. Historical documents show primarily that climate in China varies usually between warm-dry and cold-wet episode. The predominant character is of warm-dry in the Huanghe River and cold-wet in the Changjiang River. However, rainfall in China changes nonlinearly in general with temperature. Predominance of warm-dry or cold-wet regimes does not exclude other combination of rainfall and temperature changes in some periods and in some region. It is more complex when the anthropogenic impact was considered. The global warming may intensify the Indian summer monsoon, and increase monsoon rainfall. But no any parallelism was found between summer rainfall in India and in China, especially in South China.

Climatic disasters are one of the complex and important problems to which great efforts should devote. Research in this field will benefit to agriculture and society in general. However it is impossible to elaborate in a collected papers based on studies within a few years. Therefore, present collected papers provides only a summarization of the main research results of this topic. A great deal of research work should be required before a more robust conclusion can be made.

This collected papers was edited by Guo Qiyun (Institute of Geography, Chinese Academy of Sciences), Wu Guoxiong (Institute of Atmospheric Physics, Chinese Academy of Science) and Sun Anjian (National Climate Center, Chinese Meteorological Administration).

Prof. Guo Qiyun

Executive of the 1st topic of Project "KY85-10",

the Key Applied Project of Chinese Academy of Sciences

during the 8th Five-Year-Plan

目 录