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

灾害性气候的过程及诊断

KY85-10-2

主　编：黄荣辉
副主编：陈烈庭 翁学传 宋正山

DISASTROUS CLIMATE

气象出版社

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，且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灾害性气候成因及形成过程部分，即上述第二课题内容。它包括大气环流异常、大气外强迫作用（如青藏高原、冰雪覆盖、海洋热力效应及陆面过程等）与灾害性气候的关系等方面的研究成果内容，对认识灾害气候的形成规律和提供新的预报线索具有重要意义。

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。由于时间匆忙，文中肯定有不少不妥之处，恳请指正。

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.

This collected papers are the part associated with the studies on the causes and formation processes of the disastrous climate occurred in China in the series of the collected papers published for the summaries of investigated results of this project, i. e. , the content of the second research topic mentioned above. The results investigated on the relation of the disastrous climate to atmospheric circulation anomalies, external forcing effects, such as the Tibetan Plateau, the snow and ice covers, the thermal effect of ocean and land surface processes etc. are included in the collected papers. This collected papers have an important meaning for the understanding of the formation of the disastrous climate occurred in China and for the proposing a new forecasting approach.

The object of this collected papers is to promote the exchange between the institute associated with climate prediction and the operational divisions of climate prediction. Since the time written 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

“灾害性气候的形成过程及诊断研究”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）的第二个研究课题。

灾害性气候预测问题的研究对国民经济建设、社会发展和人民生活具有至关重要的意义，也是当今地球科学的前沿课题之一。为了提高灾害性气候预测的水平，建立一套有效的预测方法是非常必要的。为此，首先必须分析灾害性气候形成的长期过程，了解其发生的物理原因，并从中提炼出对气候预测有帮助的规律和线索，这是本课题研究的中心内容。根据当前国内外有关领域研究的现状和我们已有的研究基础，本课题设立了以下四个相互联系的研究专题：

1. 大气环流异常对灾害性气候的影响；

2. 青藏高原和冰川、积雪变化对灾害性气候的影响；

3. 海面热力效应和海气相互作用与灾害性气候的关系；

4. 陆面状态改变和陆气相互作用与灾害性气候的关系。

几年来，我们在以上四个方面作了大量深入的研究。工作中力图以新的观点和方法，并尽可能多地分析气候异常事件，特别是引起我国长江、黄河流域严重旱涝的那些灾害性气候典型个例，揭示其与大气环流持续性异常及季风活动变异的关系，阐明气候异常发生、发展的长期天气过程，及其与大气中的低频和甚低频振荡、青藏高原的热力作用、海洋的热力效应、大陆的冰雪覆盖和其它陆面过程等的物理联系。所有这些研究，旨在探索更多新的影响因素和预报线索，为进一步改善灾害性气候的预测提供可靠的科学依据。另外，为了对所得成果进行验证，每年春季我们还将它们应用于我国汛期（6—8月）预报试验，收到了很好的效果。

本文集是课题的部分研究成果，共收集了35篇文章。其中在大气环流方面包括：夏季阻塞高压发展和维持过程的研究；东亚冬季风与夏季江淮流域旱涝的关系及其联系的物理过程的研究；ENSO与梅雨的多态相关和ENSO本身形成的可能机制的研究等。在海气相互作用方面有以深层海温（热带西太平洋和南海海域）和海气热通量（中纬度黑潮和湾流海区）代替海表水温探索新的预测方法和途径的一些研究。此外，在青藏高原和地气相互作用方面也有不少新结果。

这些成果基本上反映了前几年各专题研究的进展，后期研究成果将汇集在第二本文集中另行出版。

本文集编委会由大气物理研究所陈烈庭、宋正山、朱抱真、彭京备和青岛海洋研究所翁学传组成，文稿的绘图和计算机输入处理主要是由王婉文和杨艳霞完成的。

中国科学院“八五”重大应用项目（编号：KY85-10）
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第二课题组长：陈烈庭

Foreword

The topic"Stuby on the formation processes of disastrous climate and its diagnostics"is the 2nd research task of the key application research project"The prediction of disastrous climate and its impact on agriculture and management of water resources"(No. KY85–10), supported by Chinese Academy of Sciences during 1991—1995.

The study on disastrous climate prediction possesses significant importance to the national economic constructions, social development and human's life. In fact it has became one of the most active research fields in the earth sciences right now. In order to raise the ability to forecast the disastrous climate, it is necessary to develop a hierarchy of effective prediction methods, including statistical methods and physical models. For this, we must make efforts to diagnose and analyse the physical causes and precesses for occurrence and development of disastrous climate and find the useful rules and clues for its forecasing. These are the central contents of our research tasks. Based on the present status of relevant researches at home and abroad and our own work, we have set up the following sub–tasks:

1. Influence of persistent anomalies of atmospheric circulation, including monsoon circulation, on disastrous climate;

2. Effects of snow cover over the Qinghai–Xizang Plateau and polar ice cover on disastrous climate;

3. Relations of ocean thermodynamic effect and air–sea interaction to disastrous climate;

4. Connections of land surface process and air–surface interaction with disastrous climate.

A lot of deep researches about the above 4 sub–tasks are carried out during the recent years since 1991. In the course of work we make the widest possible use of new concepts and advanced methods and analyse the climate anomaly events as many as possible. especially the typical cases causing severe drought and flood in *Yangtze* (Changjiang) and *Yellow* (Huanghe) River Valleys. We try to reveal the relations of the persistent anomaly of atmospheric circulation and the interannual varability of monsoon activity to climate anomalies and to clarify the physical processes of occurrence and development of climate anomalies and their connections with the low and very low frequency oscillations in atmosphere, the thermodynamic state over the Qinghai–Xizang Plateau, the marine anomaly heating, the large–scale covers of ice and snow and other processes in the land surface, etc. The major purpose of all these researches is to seek more influence factors and some forecasting links and provide reliable researches is to seek more influence factors and some forecasting links and provede reliable scientific evidence for further improvement of disastrous climate prediction. Besides, in order to test and verify our findings, we apply them to the experiment prediction of rainy season rainfall in China which is conducted in spring of each year and receive good effect.

This volume is partial research results of our task, altogether 35 papers. The main contents included in the atmospheric circulation aspect are the processes of development and maintenance of blocking high in summer, the relationship between winter monsoon in East Asia and summer droughts and floods in Changjiang–Huaihe River Valleys and the physical processes of their connection, the possible mechanisms of ENSO formation and a variety of its relations to East Asia Meiyu etc. In the aspect of air–sca interaction, there are some research results by using the subsurface water temperature(in tropical western Pacific and South China Sca) and the ocean–atmosphere heat transfer(in Kuroshio and Gulf Stream regions) instead of the sea surface temperature to seek new methods and ways of prediction. Besides, some interesting results are also obtained about effects of the Qinghai–Xizang Plateau and the air–surface interaction.

The papers in this volume basically reflect the research advances of our sub–tasks during the earlier years. The work conducted during the later years will be published in the second volume.

The editorial group of this volume consists of Chen Lieting, Song Zhengshan, Zhu Baozhen, Peng Jingbei and Weng Xuechuan. The map–making of some papers and the processing of all manuscript input on computer are accomplished by Wang Wanwen and Yang Yanxia.

Prof. Chen Lieting
Executive of the 2nd topic of project KY85–10,
the Key applied roject of Chinese Academy of Sciences
during the period of the 8th Five–Year–Plan

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夏季东北亚阻塞高压形成的一种机制

吴国雄　刘　辉　赵宇澄

(大气科学和地球流体力学国家重点实验室(LASG))

(中国科学院大气物理研究所，北京 100029)

提　要

1980 年夏天，亚洲东北部有阻塞高压稳定发展，导致我国南方持续低温洪涝及北方高温干旱。本文研究时变天气系统的输送过程对该阻高形成的作用。结果表明，这种波流相互作用所导致的阻高增长过程比典型的大西洋阻高的发展还强烈得多。指出除了热带，副热带系统外，欧洲及西亚地区强斜压带的发展及其上天气尺度系统的向东传播和输送特征对我国夏季持续天气的形成也有重大影响。

一、引　言

1980 年夏天，我国出现历史上罕见的"南涝北旱"天气(图 1)。6—8 月黄河以南长江以北地区经历奇特的低温阴雨，整个长江流域出现了 1949 年以后仅次于 1954 年的特大洪水。与此相反，黄河以北地区持续高温干旱[1-3]，致使牧草枯黄，水库和河流干涸。我国广大区域上异常天气的持续性及强度为历史少见。毕慕莹和丁一汇[4]曾对该年夏季的形势进行分析，指出上述持续异常天气与东北亚阻高的稳定维持有关。本文的目的在于分析该阻高形成的机制。第二节对 1980 年 7 月的环流形势作简要介绍。第三节讨论天气尺度系统能量向阻高的转化及其对急流和阻高形成的贡献。讨论和结论将在第四节给出。

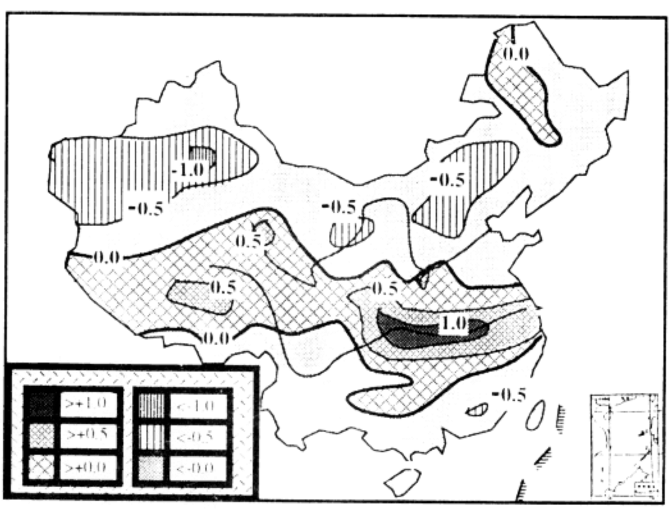
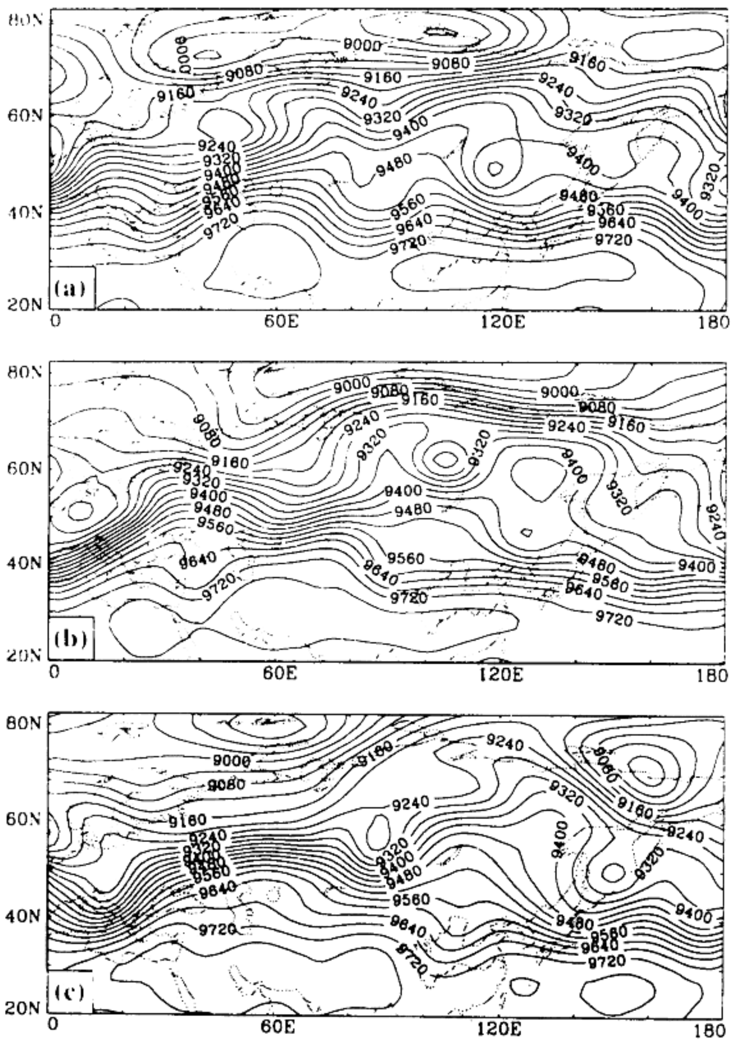


图1　1980年6—8月降水距平百分率的分布粗实线为零线，等值线间隔为0.5。格子区为正距平，其它为负距平区

二、大气环流形势

1980 年 6 月 9 日，随着副高脊线从 18°N 北跳至 22°N，以及孟加拉湾低压迅速发展，华南前汛期结束，江淮梅雨期开始。此后副高稳定少动盘踞在 22°N 左右，孟加拉湾低压也持续偏强，导致雨带一直滞留在江淮地区。这种持续异常天气还与中高纬阻塞高压在东北亚长期稳定维持有关。7 月上、中旬该阻高又经历一次重建和发展的过程。自 7 月中旬以后直至 8 月一直稳定在 110 至 150°E 之间。为研究天气尺度系统在阻高发展形成中的作用，我们选取 7 月 8—15 日一段时间进行分析。图 2 示出该段时间 300hPa 形势的演变。它清楚表明，在此期间从欧洲至中亚的斜压带上不断有天气系统发展东移。



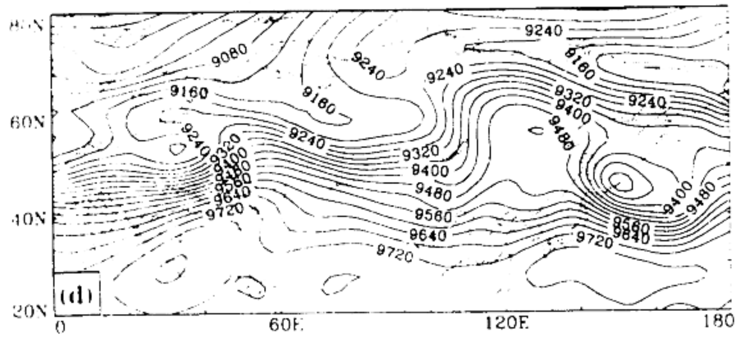


图 2　1980 年 7 月逐日 00Z 300hPa 位势高度演变。等值线间隔 80 位势米

(a)8 日；(b)10 日；(c)12 日；(d)14 日

它们在贝湖以西分流区分别移向东北和东南方向。后期东北亚阻塞高压逐渐建立。此后则一直少动[4]。为研究天气扰动在阻高形成中的作用，我们利用大气所资料中心(DCIAP)存档的 ECMWF 资料进行分析。取 300hPa 为相当正压层，对所有时变资料进行带通(2.5—6 天)虑波处理。因此下文所提"扰动"均指周期为 2.5—6 天的波动。

三、天气扰动的能量串级和阻塞的形成

Fjortoft[5]曾证明，在无辐散正压大气中，必须至少有三种尺度的波动参与，能量的转化才能实现。吴国雄[6]进一步证明，在有辐散斜压大气中，能量转化的多尺度参与原则依然成立；在弱辐散相当正压大气中，能量转化还服从双向原则：中间尺度(L_m)系统能量的减少(增加)必有较小尺度(L_s)和较大尺度(L_l)系统能量的同时增加(减少)来补偿，其量值满足下述关系：$dE_l / dE_s = (L_m^2 / L_s^2 - 1) / (1 - L_m^2 / L_l^2)$。其中$dE_l$和$dE_s$各为大尺度和小尺度系统能量的变化量。图 3 示出 7—15 日 300hPa 图上 50°N 附近 9360 位势米等高线的逐日变化。在此期间向东传播的三个天气尺度的槽在靠近贝湖时尺度大致减半($L_m / L_s \approx 2$)，呈现向较小尺度转化能量的串级现象。注意到 9 日以前东北亚只有一个弱脊。随着天气尺度系统一次次自欧洲向该高压脊移动，从 10 日起该脊逐渐发展，尺度加大，最后在 13 日呈阻塞势态，其尺度约为原天气系统尺度的一倍($L_m / L_l \approx 0.5$)。根据上述能量双向转化原理，在此过程中，80%的天气尺度能量将向时间平均阻塞高压系统转化，从而促使阻高形成。为检验天气尺度的时变系统和阻塞尺度的时均系统之间的能量转化，我们利用下式

$$C(\overline{K} \rightarrow K') = \frac{\overline{u'v'}}{a}\left[\cos\varphi\frac{\partial}{\partial\varphi}\left(\frac{\overline{u}}{\cos\varphi}\right) + \frac{1}{\cos\varphi}\frac{\partial\overline{v}}{\partial\lambda}\right]$$
$$\frac{1}{a}\left[\overline{(v')^2} - \overline{(u')^2}\right]\left[\frac{1}{\cos\varphi}\frac{\partial\overline{u}}{\partial\lambda} - \mathrm{tg}\varphi \cdot \overline{v}\right]$$

去计算时间平均动能$\overline{K}$向天气扰动动能K'的转化$C(\overline{K} \rightarrow K')$的空间分布，结果如图 4 所示。沿着急流分流区及阻高主体，均有天气系统的能量向急流和阻高等时均系统能量的转化。这与能量双向转化的结论是一致的。

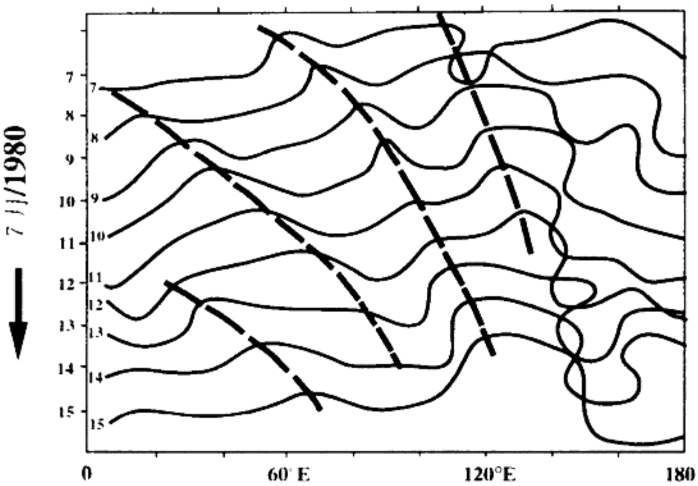


图 3　1980 年 7 月 7—15 日 300hPa 上空 50 ° N 处 9360 位势米等高线逐日演变，粗断线表示脊线

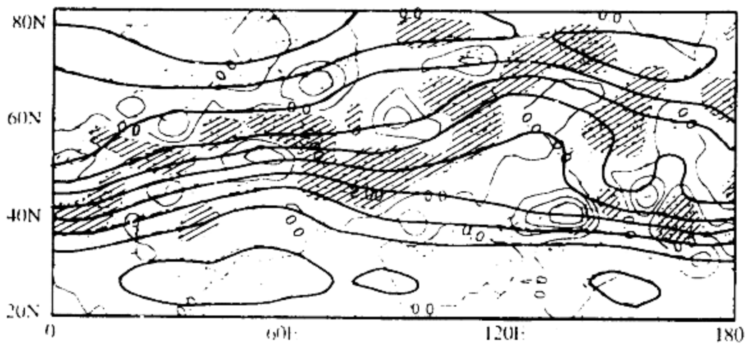


图4　1980年7月7—15日300hPa高空时间平均动能$\overline{K}$向时变动能K'转化($C(\overline{K}\rightarrow K')$)的空间分布，实线和虚线分别表示正、负值区。等值线间隔为($1\times10^{-4}\mathrm{m}^2\cdot\mathrm{s}^2$)的区域

为了估计时变涡动强迫生成阻高的速率，在略去源汇时，我们利用下述时间平均位涡方程

$$\begin{cases}\dfrac{d\overline{q}}{dt} = -D = -\nabla\cdot\overline{v'q'}\\ q = \nabla^2\psi + f - \gamma^2\psi,\ \gamma^2 = f^2(gH)^{-1}\end{cases}$$

根据逐日资料计算D的分布，并示于图 5。从图可见，在强西风带及分流区的中轴线及其以南D为正，以北D为负。因此时变扰动在急流轴以南为负位涡源，在以北为正位涡源，时间平均西风由此得以加强。更显著的是在阻高脊线及其西侧$D>0$。质块经此均得到反气旋性位涡，从而利于阻高发展。值得注意的是在脊线附近D的强度达 $0.8\times10^{-5}\mathrm{s}^{-1}/\mathrm{d}$，比著名的 1976 年夏欧洲阻高过程的最大$D$中心 ($0.5\times10^{-5}\mathrm{s}^{-1}/\mathrm{d}$)[7]还强 60%。假定阻高的位涡可强达 $-2\times10^{-5}\mathrm{s}^{-1}$，则上述时变涡动位涡输送过程的强迫作用在 3—4 天中即可使阻高形成。

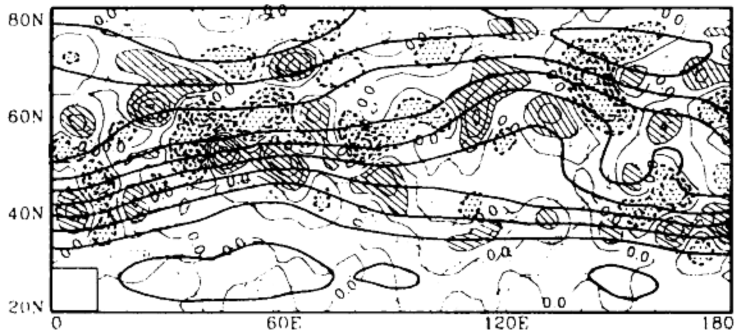


图5 1980年7月7—15日300hPa时变涡动位涡通量的平均散度D的空间分布，等值线间隔为$3\times10^{-11}s^{-2}$。斜线区表示大于$3\times10^{-11}s^{-2}$的区域，点区表示小于$(-3\times10^{-11}s^{-2})$的区域。粗实线为等高线

由时间平均位涡方程还可得到

$$\frac{\partial\overline{\Psi}}{\partial t}=(\therefore^{2}-v^{2})^{-1}(-D)+\text{其它项}$$

对图 5 给出的D场进行 Helmhotz 求逆，便可得到D对 $\frac{\partial\overline{\Psi}}{\partial t}$ 的贡献，结果如图 6 所示。涡动输送造成的正变高区出现在急流轴以南地区，并在分流区分别向东北、东南方伸展。负变高主要位于急流北测。沿急流带的南北位势梯度由此得以维持。而且，时变扰动强迫使位势高度在阻高脊线附近增加，在其上、下游下降。按图中$\frac{\partial\overline{\Psi}}{\partial t}$的分布(−10，+8，和 $-8m^2\cdot s^{-2}$)，则该脊在 8 天中可升高 70 至 80 位势米，而其上、下游的高度各可下降 100 及 80 位势米。这些数值于阻塞形势在发展中的变化(参见图 2)颇接近。

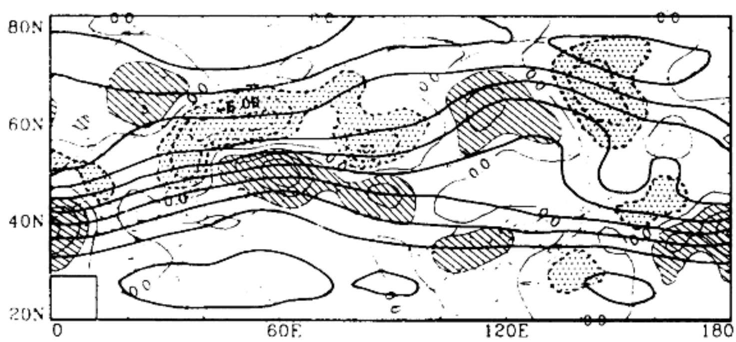


图6 由图5计得的时均流函数的局地变化($\frac{\partial\overline{\Psi}}{\partial t}$)的空间分布等值线间隔为$3m^2\cdot s^{-2}$。斜线区为大于$3m^2\cdot s^{-2}$区，点区为小于$(-3m^2\cdot s^{-2})$区。粗实线为等高线

本节的分析从而证明，至少在本例中，时变涡动输送起着维持时均急流及促使阻高发生发展的作用。