暴雨预报的理论与实践

林必元　著

气象出版社

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内容提要

本书内容有对中尺度气象学历史发展的评述，有对提高预报准确率的探讨，但更多的是对暴雨预报理论和实践的探索。其中涉及暴雨的分类，致洪暴雨的分析，暴雨的落区预报，夏季风与梅雨的关系，降水的量级预报方法，湿度场的突变对暴雨的影响，以及西太平洋副热带高压的活动与暴雨的关系等。

本书兼具暴雨预报的理论和实践两个方面，在叙述上舍深求浅，适合广大气象工作者，特别是各级台站预报员、气象科研人员以及大专院校的师生参考。

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前 言

我从事天气预报工作三十多年。在这三十多年中，养成了这样的习惯，那就是做出每一次预报之后，不管是对是错，都要问一个为什么，并把它记录下来。本书就是这些自问的结果。书中共收录了19篇文章。这些论文，有的在国际会议上进行了交流，有的在国内学术会议上宣读过，有的散见于各种气象刊物。几乎每一篇都是根据自己日常的业务工作实践完成的。因此，既有预报经验的总结，又有浅近的理论分析，所以取名为《暴雨预报的理论与实践》。收入本书的只是关于暴雨预报的一部分论文，其他论文已收入《地形对降水影响的研究》和《中尺度暴雨分析和预报》两书中。

我国大规模的暴雨预报的研究是从1975年8月河南大暴雨发生之后开始的，至今已经三十多年。本人经历了我国暴雨研究的这一迅速发展的时期。因此，书中的每一篇文章都不可避免地打上了这一历史时期的烙印。在可以预见的将来，暴雨预报仍然是气象学中最困难的问题之一。本书如能有助于解决这一难题于万一，那将是作者最大的欣慰。

本书在成书过程中，得到了湖南省气象台黎祖贤台长的大力支持。书中的部分图表和计算机处理及操作方面的工作是林海完成的。湖南省气象台的何静同志为本书的资料整理付出了辛勤的劳动。在此一并表示衷心的感谢。

作者

2006年5月于长沙

目　录

Canalization and Meso-γ Scale Rainstorm*

LIN Biyuan YIN Ming

1 Introduction

There is a meteorological station named Dongkou in Hunan Province of south China, where always drop rainstorm, but all the around area have no precipitation, so the weather forecaster in provincial station generally regarded it as a wrong record. As the same thing always happen, meteorological office of Hunan Province send me to have an investigation. This paper analyzed the local violent flood in Dongkou, Hunan Province on May 26,1986, studied the meso-γ scale canalization effect on violent flood.

2 Basic facts

2.1 Rainfall

From 2:00 a. m. to 8:00 a. m. on May 26,1986 there is a super rainstorm in Dongkou,Hunan Province, resulting in mountain flood. The amount of precipitation is 207. 8 mm between 2:25 to 6:30 and the largest amount of precipitation within 1 hour is 111. 6mm. The 3h,1h,10min amount of precipitation exceeded provincial record in history, and closed to the domestic maximum value.

The rainstorm spread like a band along eastern limb of Xuefeng Mountain, it is about 5—10km wide,40km long. The core of the storm is located in Dongkou town. The horizontal gradient is very large. It basically belongs to meso-γ scale violent flood, and this kind of violent flood only happens in Dongkou.

To analysis the process of this violent flood, we must make it clear that: How does the rainstorm happen? Why is the scale so small and is the intensity so strong? Why is the core located in Dongkou?

* 本文在 2000 年第 13 届云和降水国际会议上交流。

2.2 Topography

Dongkou lies in the south-east of Xuefen Mountain, west of Shaoyang Basin. Shaoyang is located between Xuefen Mountain and Yuecheng Mountain. There is a NW-SE canyon in the middle of Xuefen Mountain. The depth of the canyon is over 1000m, the width is about 200－400m and the length is about 40km, which forms a deep and long pipeline, and the exit is in the NE sides of SE end of the pipeline(see Fig. 1).

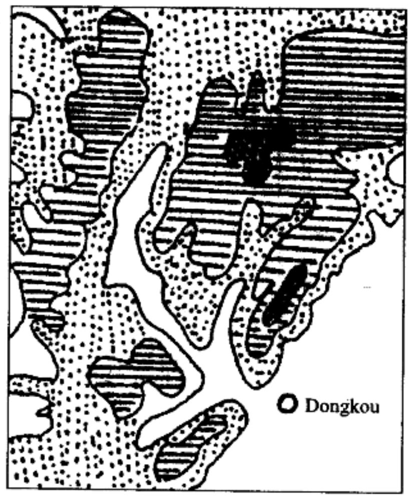

Fig. 1. The canyon of Xuefeng Mountain

2.3 Background field

On 20:00 BT May 25, there is no any trough system at the line of 500hPa, which could make rainstorm, no matter before the rainstorm or after the rainstorm, this area is controlled by 500hPa anticyclone, and the wind field is weak. At the same time, there is no any trough system at 700hPa either, all the area of south China is in the homogeneous field of pressure and temperature, the wind field is weak. Though there is a trough between Xi'an City and Chengdu City, but it didn't work at all within 12 hours, so it isn't the trough which directly produced the Dongkou rainstorm. But the 850hPa Sichuan trough moved obviously within 12 hours, it is the meso-α scale system which made the Dongkou rainstorm.

2.4 Mesoscale weather system

Before the rainstorm, there is a obvious landform pressure of low-mid at the south-west of the storm source. As the inrush of the cold front, the pressure of low-mid became half warm and half cold, so it grew and moved near to Dongkou, where it formed one dual pressure with small high pressure after front, it is the direct maker of the rainstorm process.

2.5 Ground heat field

Diurnal evolution of ground heat field: The bottom glade of Yuan River and Mayang basin are area of low value of heat field, but mountains are area of high value at 09 BT on 25. However the condition is just antithesis.

Section of heat field and degree of stability of stratification: Afternoon on 25 Mayang Basin and Xuefeng Mountains are warm area at all times. Ground heat field changes atmosphere stratification rapidly. It animates water vapour go to high level from low level and deep degree of humidity layer increate . Because wind field of weather system is weak, above evolution course can persist at a long times.

Anomaly increasing of temperature: Generally temperature is declining in 02 BT in summer by evolution of temperature field in day. There is an anomaly area of increasing temperature near by Dongkou at 02 BT on 26, which is an indication before rainstorm. Increasing temperature is not inconsistent, the anomaly area of increasing temperature is small and the area is just about location of rainstorm.

2.6 Humidity field analysis

The features of the rainstorm are in the following. Weather map shows that there is an area of high humidity nearby Zijiang and Tongdao, also is so from east of Sichuan to southwest of Hubei, the late is relevance with rainstorm location of front. Above two high humidity areas were cut by cold-dry air from Yuanjiang canyon, so about Zijiang comes into being a lone high humidity area of mesoscale. Meso analysis shows there there is a dry centre of the east side of Xuefeng Mountains, but a wet centre of the west of the mountains. The parts of dry and humidity are long shape of north-south direction. The weak cold air comes into east side of Xuefeng Mountains. The part of north humidity area moves to east before rainstorm. When the thunderstorm close with, Xuefang mountains are just general humidity area. The wet section is located in west of the rainstorm and wind goes to east from west in the canyon, so water vapour passes by the canyon to rainstorm location.

Vertical distribution of difference of dew point temperature: Figure 2 shows that before the rainstorm 450—250hPa is the greatest level of increasing humidity, 950—750hPa is second, change of humidity is not obvious in the 700—600hPa level, by comparison 600—500hPa is a dry level. However, when the rainstorm stars 600—500hPa level is more and more dry, and humidity difference of the dry level with another wet levels is more and more large. This dynamic of dry level changes degree of stability in atmosphere and accumulates energy and supports downdraft of cumulus. Aside from a deeper saturation level from the ground to 600hPa, nearby 400hPa is a saturation level too.

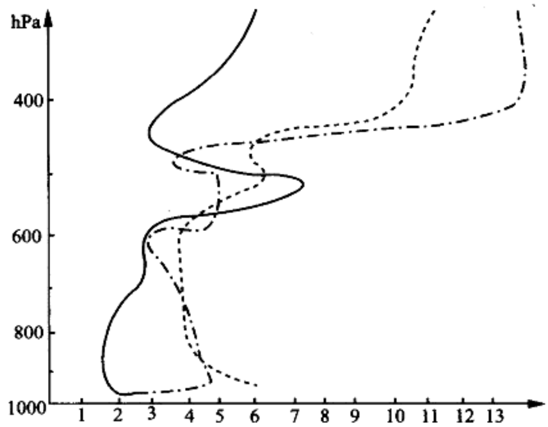

Fig. 2. $T-T_d$ line, on May 25, 1986. (08 BT is dot-dashed, 20 BT is dashed) and in the next day 08 BT (it's solid)

2.7 The temperature inversion

In temperature altitude chart at 08 BT on 25 before rainstorm there are some levels of temperature inversion, where by 600hPa level is the best obvious, In temperature altitude chart at 08 BT on 26 during rainstorm there is no any level of temperature inversion in the midst level, by 900hPa is only level of temperature inversion.

2.8 Canalization effect

The air stream of pass by canyon causes west wind at Dongkou, but it is east wind in the east aside of the mountains, so a convergence point appears in Dongkou. The air stream of exit of the canyon leads two circulation systems of meso-small scale, one is low pressure loop in north of Dongkou air exit and another is high pressure loop in the south. The two loops are in relation to the rainstorm. The analysis of pressure field of 1 hour indicates too two pressure loops. When wind passes by Dongkou, difference value of the dual pressure increases obviously.

2.9 MCC and multi-cell

The top of "Ω" anamorphic cold front on the ground produces a MCC (Meso-scale Convective Complex) at 20 BT on 25. This MCC is just coincidence with a convergence point on inversion trough of 850hPa. This convergence point had changed a meso-β scale whirl which horizontal scale is correspond with MCC at 08 BT on 26. The MCC development is vigorous and a renascent multi-cell become tie shape at 02 BT on 26. This multi-cell develops rapidly and strong precipitation falls down frantically.

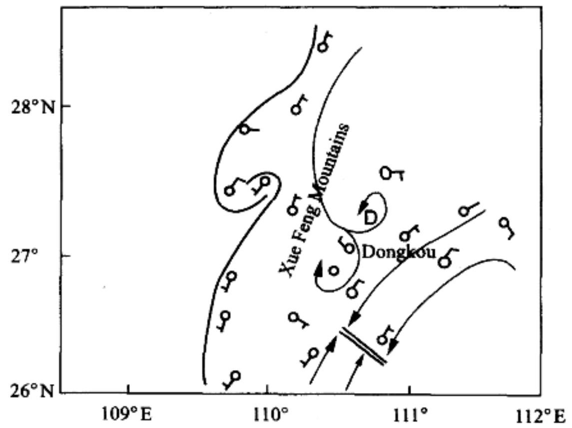

Fig. 3. Streamline field small scale at 19 BT on 25 May, 1986

3 Concept model

On the grounds of above-mentioned a concept model was expounded: In a weak weather scale wind field there is a weak cold front on the ground and ground heat is obvious ahead. There is a meso-α scale convergence area which produces a MCC on low level. There is a meso-α scale high pressure which is divergence on middle level. There is a shallow dry level on 500hPa. In vertical distribution of humidity dry and wet is interlace. When weak cold front come into convergence area and meet with mountains of north-south direction, it take place metamorphosis and changes to "Ω" shape cold front. The top of "Ω" anamorphic cold front is a high value area of temperature and humidity and a meso-α scale mid-low pressure occurrences. Anamorphic cold front go forward and lead a inversion temperature level above . Then canalization effect leads one dual meso-γ scale pressure. Updraft breaks through inversion temperature of middle level and multi-cell develops rapidly and downpour falls down frantically.

4 Forecast

Following conditions are important:

Wind fields is weaker and there is no any trough and ridge on 700hPa and 500hPa. There is a meso-α scale high pressure on 500hPa an inversion trough on 850hPa in the forecast area. Weak cold front moves to local station and ground heat is obvious ahead the front. The forecast area is located to convergence section of east slope of mountains and meso-scale low pressure appears and develops. From ground to 400hPa there are some inversion temperature layers and a deeper saturation level in which there is dry layer from 600hPa to 450hPa. Multi-cell and super-cell are vigorous on south-east side of MCC.

5 Conclusion

Above analysis shows that complex topography leads anamorphic cold front which is important reason. Dry layer in deeper wet layer have specific dynamic effect. Canalization effect can produce convergence point and cause meso-γ scale low pressure and updraft break through inversion temperature of middle level and multi-cell develops rapidly and downpour falls down frantically.

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A Study of Qinghai-Xizang Plateau Lee Wave Rainstorm*

LIN Biyuan SUN Hong LIN Xiaolu

In some torrential rain courses of the middle and upper reaches of the Changjiang River, at 12 hours before the torrential rain process happened, there is no a trough above Sichuan Basin in 500hPa. When the torrential rain is going to happen; the small trough appeared suddenly above Sichuan Basin in 500hPa. This type of rainstorm is not only difficult to predict, but also difficult to find the real reason which produces the torrential rain in analyse afterwards, it is a kind of difficult torrential rain in fact. analysis and study this kind of torrential rain course is very meaningful to real torrential rain prediction. Now at example of July 3—6 1983 torrential rain happened in middle and upper reaches of the Changjiang River, we discuss the prediction problems of torrential rain.

1 The type of 500hPa lee wave

The torrential rain course in the middle and upper reaches of the Changjiang River for July 3—6, 1983, was consist of two torrentials rains. The first torrential rain was from 22 o'clock third day to 17 o'clock forth day; The second one was from 5 o'clock fifth day to 17 o'clock sixth day. We find out from Fig. 1 and Fig. 2, before two torrential rain courses begin, 500hPa in the upper reach area of the Changjiang Rive, has no low value system, the torrential rain situation is not very obvious, so it's difficult to make torrential rain prediction. But we can see from Fig. 1 and Fig. 2, from Sichuan Basin to Qinghai-Tibet Plateau southern side, there are large stretch of southwest air current areas. After 12 hours, a small-scale low troughs has appeared in Sichuan Basin. Obviously, the torrential rain was caused by this low trough. So the question lies in being clarified the natures of low trough and predicted it.

1.1 An environmental condition helping the small trough to produce

(1) Topography. We know, in the east of Qinghai-Tibet Plateau, the Hengduan Mountain lies across west of the basin, form a natural protective barrier. The highest peak of Hengduan Mountain is higher than 5000m, with great drop between Sichuan Basin. Above-mentioned low troughs were just produced under the topographical condition.

* 本文在 2004 年美国气象学会第 11 届山地气象会议上交流。

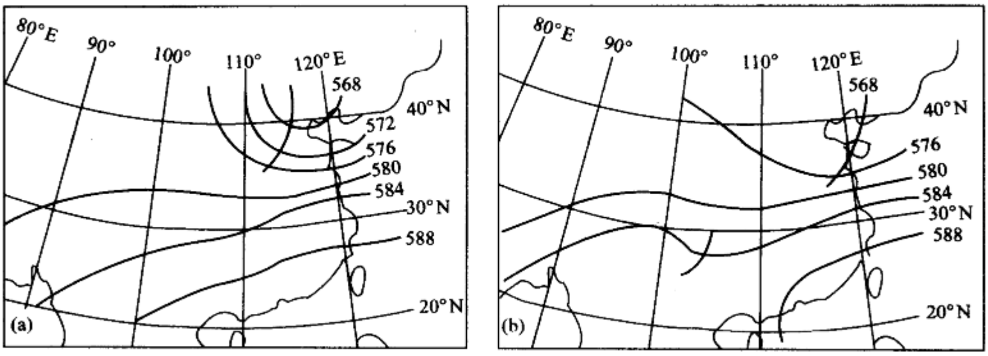

Fig. 1. 20:00,3 July 1983(a)and 08:00,4 July 1983(b) 500 hPa

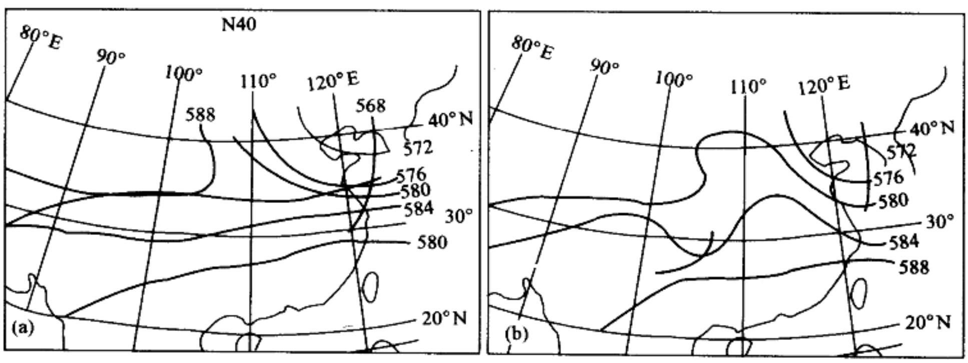

Fig. 2. 20:00,4 July 1983(a)and 08:00,5 July 1983(b) 500 hPa

(2)The air current. From Fig. 1 and Fig. 2 we can see at 20 o'clock third day and 20 o'clock forth day, that vast area of middle-south of Qinghai-Tibet Plateau (35°N) existed an area of W—SW air stream. At 8 o'clock third day, the centre of largest wind speed was located in Lijiang, the largest wind speed reached 18 m/s; at 20 o'clock third day, wind speed center moved to Xichang (the mountain ridge), its value was 20 m/s; At 8 o'clock forth day, the largest wind speed centre moved to Enshi (behind the mountain), its value slightly reduced, it is 16 m/s. At 20 o'clock forth day, another largest wind speed center appeared also in Xichang, the value was 20 m/s. At 08 o'clock fifth day, this centre moved to Enshi. Not only the little trough of Sichuan Basin appeared just at 08 o'clock forth day and 08 o'clock fifth day, when the largest wind speed center passed the Hengduan mountain, but also from ground to 500 hPa, before little trough appeared (20 o'clocks third day and 20 o'clock forth day), It is W—SW air current between the higher and lower level. This phenomenon and little troughs didn't appear at the other time (Table 1).

Table 1. Wind in Lijiang station during 3—6, July 1983

day		3	3	4	4	5	5	6	6
time		08	20	08	20	08	20	08	20
Ground	Wind direction	SW	W	W	SW	E	W	SW	SSW
	Wind speed	2	6	6	4	4	8	4	6
700hPa	Wind direction	NW	SW	SW	SW	SW	NW		SW
	Wind speed	8	8	8	6	8	10		8
500hPa	Wind direction	W	W	NW	SW	W	W	W	NW
	Wind speed	18	12	12	12	8	8	6	4

(3) Stability of stratification. During 2—5 July, the atmospheres of 1000—500hPa, appeared stable stratification at 20 o'clock first day in front of the mountain(Tengchong), and at 08 o'clock third day in the mountain ridge(Xichang). The layer of knots became stable at 20 o'clock third day behind the mountain (Chongqing). The steady layer spread eastward with the strong wind centre, see Fig. 3. Therefore, the small trough in Sichuan Basin happens under the condition that the atmosphere is stability in front of and behind the mountain. Further analysis shows that the stability stratification forms, because upper layer temperature is increased and lower layer temperature is decreased. In front of the mountain, at 20 o'clock 1st day, (stratification began stable) the temperature is increased in 500—700hPa and temperature of ground is decreased, see Fig. 4(a). In the mountain ridge, the temperature in 500hPa is increased and it induced from the ground to 700hPa at 08:00 3rd, (stratification began stability), see Fig. 4(b). At 20:00 3rd, (stratification began stability) the temperature is increased from 500—700hPa and it induced from 850hPa to ground in behind of the mountain, see Fig. 4(c). Hence temperature-difference between upper and lower become little, stratification becomes steady. It can see that the temperature-rise is earlier in 500hPa than in 700hPa from Fig. 4(c), and the air temperature on the ground reduced is earlier than in 850hPa. Just this time, the small trough appeared in

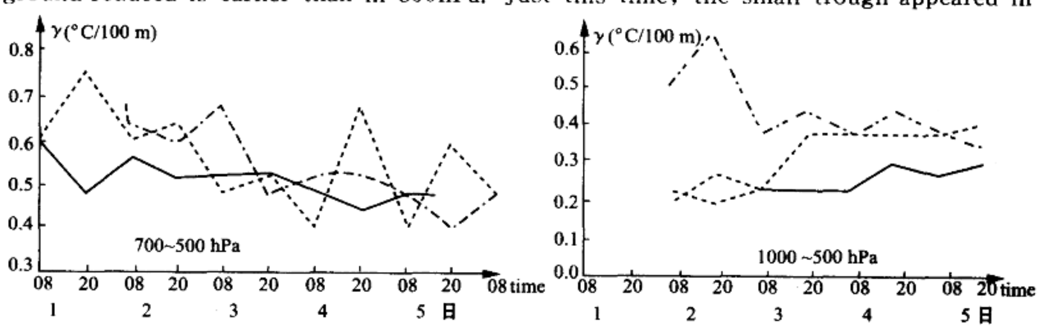

Fig. 3. Degree of stratification stability during Jul. 1—6, 1983
Tengchong(front of mountain. Solid line), Xichang(ridge of mountain, dashed line), Chongqing (behind of mountain, dot dash line)

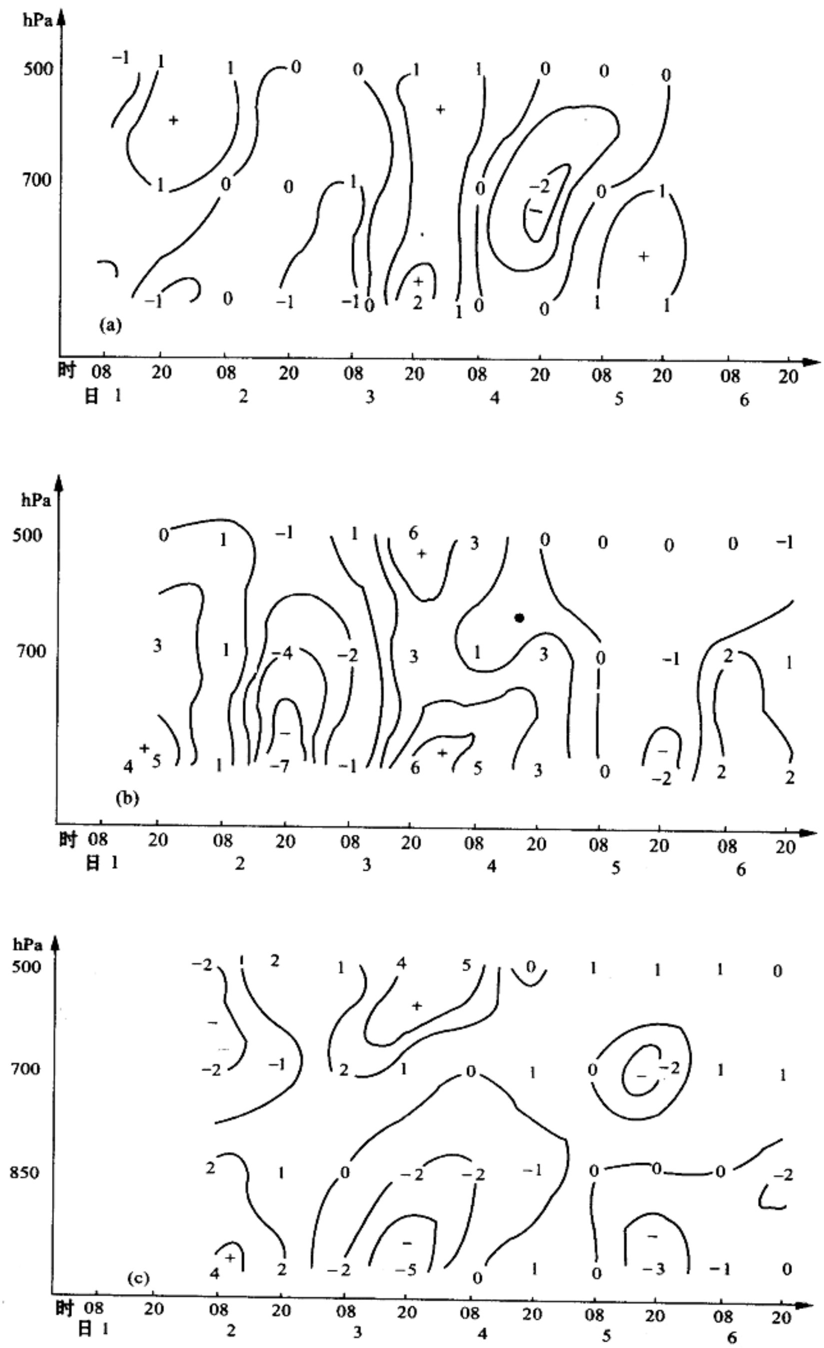

Fig. 4. 24hours temperature-difference during 1—6, July 1983
Tenchong(a) Xichang(b) Chongqing(c)

500hPa above Sichuan Basin. These environmental conditions are just helpful of forming lee wave.

1.2 Fundamental feature of small trough in 500hPa above Sichuan Basin

(1)The time scale is less than 12 hours;

(2)The space scale is about 500 km, equal of north and south distance belong meso-α scale;

(3)This trough is moved slowly and presented the quasi-stationary state;

(4)These small troughs appear when the centre of wind speed of W—SW air current moved behind mountain, and exist or die with the size and existence of W—SW air current in front of the mountains;

(5)These troughs are warm. These characteristics are in accordance with the basic characteristic of lee wave.

1.3 The analysis of precipitation course

(1)The precipitation centre. There are two strong precipitation centres. One is in Wufeng, the other is in Luotian (see Fig. 5).

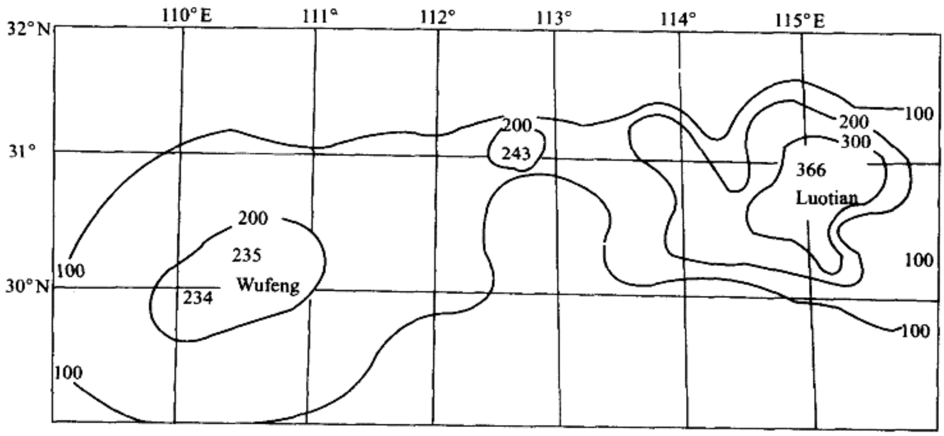

Fig. 5. Total precipitation content (mm) during 3—6 July, 1983

These two centres are in correspondence with the two wave troughs of lee;

(2) Precipitations of two centres exist seesaw structure.

Table 2. Precipitation content (mm) during 4—6 July, 1983

during	20:00,4 th to 08:00 5 th	08:00,5 th to 08:00 6 th	08:00,6 th to 17:00 6 th
Wufeng	0.3	95.1	8.3
Luotia	134.1	5.1	30.6

2 Genesis and development of lower eddy in lower layer

Because the lee trough in 500hPa appeared, field of pressure of lower atmosphere layer is influenced obviously. At 08 o'clock the 4th day the negative center of the 700hPa and 850hPa appeared in the waves troughs. It makes meso - α scale low eddy in Yibin(850hPa) developed simultaneous, there was a meso-β scale cyclogenesis in Hankou(850hPa).

3 Prediction of lee torrential rain following is important:

(1) Topography, abruptness of mountain is large;

(2) Wind speed is more than 12m/s;

(3)Air temperature in 500hPa rises suddenly;

(4)Stratification is stability, $\gamma<0.3$℃/100m(in front of mountain), $\gamma<0.4$℃/100m (in ridge of mountain), $\gamma<0.5$℃/100m(in behind of mountain), γ is lapse rate of temperature.

4 Summary

Main conclusions in this paper is in the following:

(1) Some torrential rain in middle and upper reached area of Changjiang River are caused by the lee trough in Qinghai-Xizang Plateau.

(2)This lee trough appearance is sudden. It can be a lee wave.

(3)The lee wave can cause a meso-β scale low eddy.

(4)Precipitation of two centre in lee rainstorm exists seesaw phenomenon.