On the Development of Meso-Scale Heavy Rain Parcels in China

Zhang Yan (章 淹)
Beijing Institute of Meteorology, Beijing 100081
Received March 10, 1994; revised March 22, 1994

ABSTRACT

Heavy rains occur in China frequently, which often bring us floods and serious disasters in the summer half-year. The meso-scale heavy rain parcels (MHRP) in the mid-latitude are usually developed in following cases:

I. By the approaching, meeting and / or overlapping of different weather systems, when two or more different rainfall systems are getting to conjugate, some MHRPs could be developed, such as: 1) a new cold / warm front or squall line approaches an old front or squall, even when the old one is somewhat decrepit; 2) at the places where two or more synoptic systems with different characteristics are meeting together, such as the meeting of tropical cyclone with the cold airs coming from the mid- and / or high-latitudes, or the low latitude vortex meeting with the westerly trough; 3) at the intersections of some different weather systems, such as the intersection of drylines, squall lines or fronts moving from different directions; and 4) by the overlapping of rainfall parcels produced continuously from a meso-generation centre.

II. Resonance Effect and Tibetan Plateau Influence are two reasons why high frequency of heavy and torrential rains arround the meiyu front is discussed also.

Key words: Meso-scale heavy rain parcels (MHRP), Forcing field, Interactions of different weather systems, Resonance effect, Tibetan Plateau influence.

I. INTRODUCTION

Heavy rain, a kind of severe weather, often occurs in various parts of China, and some of its precipitation had reached the world extremes. The rainy period is mainly in warmer season, and the longest duration can last for about eight months. By and large, the frequency and the duration are gradually decreasing from South to North China and from coastal zone to inland. But some extremely intensive heavy rains can also be produced in North China, such as the torrential rains happened around Beijing and Tianjin in July 1939 (Zhang Yan, 1992) and in Hebei Province, in August 1963 that had caused two very serious flood events in North China. The latter heavy rain process attained a record of 2051 mm in seven days (Zhang Yan, 1989) Even though a world record of 1400 mm / 10 hr desert heavy rain occurred in the Maowusu Desert of Inner Mongolia in August, 1977 (He Qing, 1987).

Heavy rain often causes severe disasters. On the other hand, however it is also a kind of precious water resources for the arid or semi-arid regions. Therefore, research and forecasting of heavy rain is an important task for the meteorologists of China.

Actually, heavy rains are always limited in area, especially the intensive heavy rains usually in a meso-and / or mini-scale area within the precipitative place. So we called it the Meso-scale Heavy Rain Parcel (MHRP). It is very important and difficult for us to recognize of MHRP when it is still in the primary stage. Therefore to study the development of MHRP might be beneficial.

Fig. 1. Satellite cloud picture (IR) showing MHRP's (E, S, X, L) developed by the southwesterly low level jet from South China Sea.

Fig. 2. Satellite cloud picture (IR) showing MHRP's (C, C) formed in the upper level divergence and lower level convergence field, white line—stream line of 200 hPa, dotted line—stream line of 850 hPa.

II. RELATIONSHIPS BETWEEN MHRP AND ITS FORCING FLELDS

Although heavy rains are usually connected with the mesoscale weather systems directly, for intensive heavy rains apart from their mesoscale settings, they always last a certain long period of duration (usually more than half a day); their accumulative rainfalls reach a disastrous standard of more than 200 (or 400) mm / 24 hr. As to torrential rains, except those caused by tropical systems which usually occur within 1–3 hours, suffcient water supply and regeneration conditions of precipitative systems are required, i.e the forcing mechanism produced in the synoptical–scale forcing fields, including the moisture and energy transport by low level jets (Fig. 1) (Chen Weimin et al., 1988), the formation and maintenance of uplifting by high level divergence / negative vorticity and low level convergence / positive vorticity (Fig. 2), and some topographic influences; the convergence, or the shear lines and the gravitational waves etc.

Hence, the comprehensive studies of mesoscale systems and their forcing fields are important.

III. INTERACTIONS OF DIFFERENT WEATHER SYSTEMS AND THEIR INFLUENCE ON TEH DEVELOPMENT OF MHRP

Heavy rain may be developed within a single weather system (single air–mass), e, g. in low pressure system, typhoon and / or strong convective thunderstorm etc. But, recently, we found that a great number of MHRP's are developed by the approaching, meeting and / or overlapping of two or more different weather systems when these precipitative systems are getting into conjugation:

1. *By the Interaction of a Newly Approaching System with the Former One*

Some MHRP's are produced when a newly coming trough / vortex, or a cold / warm front, or a squall / dryline is moving swiftly and approaches, or intersects with a former existing system of the same kind. MHRP's can be formed by two conjugating systems, both are not strong, or even in some cases, the former one is in the decaied stage. Such as:

(1). *At the intermediate place between two closing systems*

MHRP's developed when a newly approaching system is moving swiftly near existing system, such as the case of May 30–31, 1980 (Zhang et al., 1990) shown in Fig. 3. An upper level trough with a cold front (cloud band A, B) from Northwest China was moving and approaching to a former existing and weakening quasi–stationary front (E, F) over the Yangtze River Valley on May 30, 1980 (Fig. 3a). And after the cloud band (AB) moved eastward about 10° longitudes and approached the rear part of existing front on May 31, 1980. It is very interesting and difficult to forecast that two MHRP's (C, D) developed between these two quite closed systems. At the meantime the stationary front was seemingly disappeared (Fig. 3b).

(2). *At the intersection place of two conjugated systems*

Low pressure trough coming from Northwest China and / or low vortex moving from Southwest China often intersects with the existing front, wind shear line or quasi–stationary front in the central and East China. MHRP's usually developed when these two weater systems are meeting together, for example, as shown in Fig. 4 (Chen, 1980) which is a typical example of this type of heavy rain. An eastward moving low trough with a cold front cloud system (AB)extending approximately in N–S direction was moving and intersecting with the existing quasi–stationary front (DE) distributed approximately in W–E direction over the Yangtze and Huaihe River Valley by the northern side of subtropical high. Both of these two

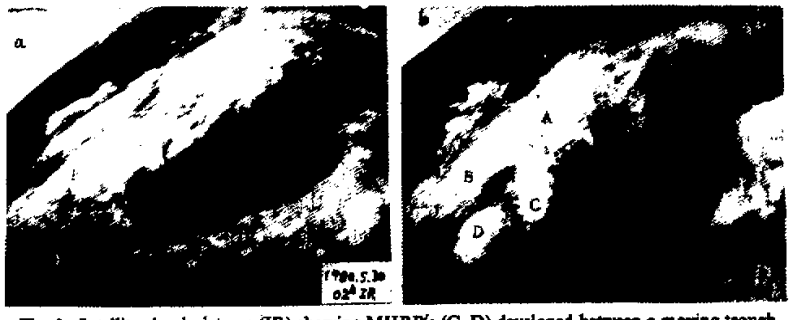

Fig. 3. Satellite cloud pictures (IR) showing MHRP's (C, D) developed between a moving trough approaches to a weakening stationary front.

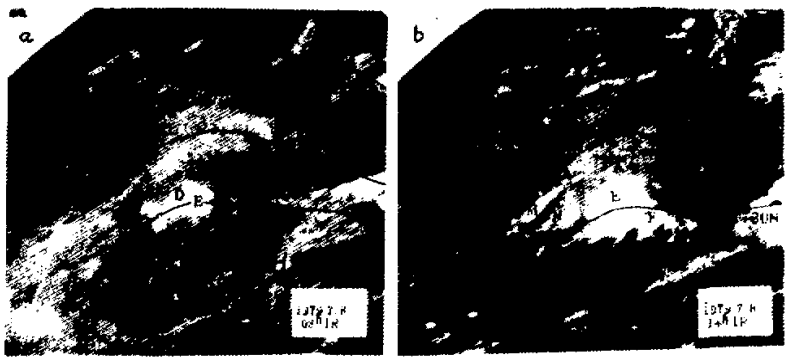

Fig. 4. Satellite cloud pictures (IR) showing MHRP's (M, N, E, F)developed by the intersection of two conjugated systems.

systems were not strong (Fig. 4a). But by the interaction, MHRP's (C, D) developed firstly at their cross–section place; then according to the eastward moving of the cross–section enhanced these two weather systems and MHRP's (M, N, E, F) were further developed (Fig. 4b). This type of MHRP often occurs arround the meiyu fronts in the rainy season.

2. *MHRP Developed by Interaction of Weather Systems of Different Characters and Different Latitudes*

MHRP can be generated by the interaction and / or combination of different weather systems of different characters (or air–masses) from high–, mid– and low– latitudes, such as:

(1). *Frontal heavy rain*

Which is well known and would not be discussed here again.

(2). *Interaction of low pressure trough in westerlies of mid– and high–latitudes with the systems of mid– and low–latitudes*

MHRP may be developed when a low pressure system in the westerlies of mid–and high–latitudes is in conjugation with the southwesterly monsoon flow and / or the low level jet stream from mid–and low–latitudes. An example as shown in Fig. 5a, low pressure trough in the westerlies of mid–and high–latitudes in the upper part of the image where the cloud system in front of the trough is not strongly developed; and a scattered cloud system of the southwesterly flow in the lower part of the image, but MHRP's (A, B) developed at the connection place of these two systems.

(3). *Combination or overlapping of plateau cloud system with another system*

Tibetan Plateau–so called "The roof of the world" is situated in the southwestern part of China. Owing to the topographic influences and the thermal and dynamic processes, gravitational waves and turbulences often appear over the plateau. Meanwhile, a lee–side low system, " Southwest Vortex" lies to the east side of the plateau frequently, and non–geostrophic air–flow and cyclonic CFig. 6loud systems often form over the SW Vortex region. The positive vorticity advections and MHRP's usually develop when these plateau systems are moving eastwards and in combination with other weather systems. An example of

Fig. 5. Satellite cloud picture (IR) showing MHRP's (A, B) developed at the connection place of two different systems in westerlies.

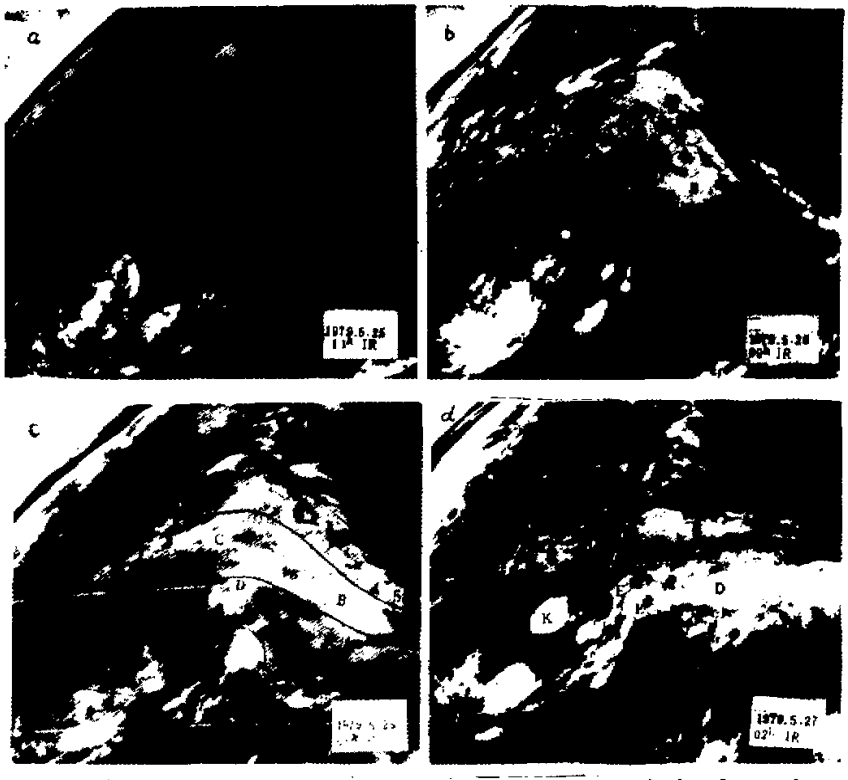

Fig. 6. Satellite cloud pictures (IR) showing MHRP's developed by the combination of eastward moving of plateau system with other systems downstream.

this type (May 25–27, 1979) is shown in Fig. 6. A typical plateau cloud system (C) of cellular form is generated over Tibet and a westerly low trough cloud system (AB) appeared to the east of the plateau (Fig. 6a). Afterwards, the plateau cloud system moving eastwards out of Tibet and conjugating with the trough cloud system (AB). Then, as shown in Fig. 6b, relatively strong cloud-mass (D) began to present when these two weather systems began to meet;

Fig. 7. Satellite cloud pictures (IR) showing MHRP (C) developed by the conjugation of tropical cyclone and low pressure trough with cold front.

and later on, MHRP's (C, D, E, F and K) developed further stronger in Figs. 6c–d. At that time, torrential rains happened in Jiangxi and Zhejiang provinces.

This kind of heavy (or torrential) rain processes frequently occurred in the summer half–year, especially in the meiyu period in the central and eastern parts of China. This is also one of the main reasons why heavy rains often appear in the subtropical zone of China, while there are a number of well–known and large deserts located under the subtropical high in other continents.

(4). *Conjugation of tropical systems with the others*

Tropical systems, such as the tropical cyclone (typhoon), the easterly waves etc. commonly appear in Southeast China from May to October, the prevailing season of typhoons in the coastal region and southern China, among them, 9.6 typhoons landing every year in average. In general, large amount of precipitation formed in tropical cyclone when it is over sea, but the intensity of rainfall will vary greatly after it landed. Some of tropical cyclones are weakened or disappeared in 1–2 days, but some of them can last for 3–5 days or even much longer, especially, when it intruded into inland. MHRP's may be produced when typhoon concurs with other cold air–flows, eventhough the tropical cyclone and its associated precipitation were in the weakening stage. Some torrential rains of these conjugating type are even more intensified than in typhoon alone, such as the case happened in July, 1939 near Beijing and Tianjin (in which 9,000,000 people suffered a lot and 13, 320 died) and the extraordinary flash flood in August, 1975 in Henan Province (6 hrs rainfall 830 mm and 3 days amount up to 1605 mm) (Zhang, 1992). Fig. 7 gives a common example of this type. In Fig. 7a, (S) is the typhoon No.8209; (AB) is the cloud–band of low pressure trough with a cold–front, and (E, F) are the convective cloud–clusters of the typhoon. Then, afterwards, MHRP (C) intensified and developed when typhoon (S) approaches the cold front (Fig. 7b). Meanwhile, the other part of typhoon (S) was still in weakening.

Fig. 8. Satelite cloud pictures (IR) showing MHRP's developed by the conjugating of multiple weather systems.

Easterly wave usually appeared in summer time when the northwestern Pacific subtropical high and ITCZ are northward shifting. MHRP's may be occurred in the single easterly wave or in the conjugation with others, which are similar to the cases of tropical cyclone, but rainfalls of this type are somewhat weaker than those in typhoon in most cases.

(5). *Conjugation or meeting of multiple systems*

MHRP may occur by the conjugation or meeting of more than two different weather systems. For intstance, a case of May, 4–5, 1982 is shown in Fig. 8. There are four cloud systems: (A1–A2) is cloud band of the low trough with cold front, (D1–D2) is the thunderstorm cloud system in front of low trough, (B1–B2) is the southern branch of westerlies cloud system from the southern region of Tibet, and (C1–C2) is the cloud system extending northeastward from typhoon (S) (see Fig. 8a). On the next day (Figs. 8b–c), these four cloud systems are getting closely. Then, the scattered convective cloud masses and the MHRP's are strengthened in the connecting places of (B) and (C), and also at the east of (A) and (B) cloud bands, while typhoon (S) is gradually weakened.

IV. DISCUSSION AND CONCLUSION—RESONANCE EFFECT AND PLATEAU INFLUENCE

Through above studies we believe that the following subjects may be of interesting for further discussion:

1. *Resonance Effect*

When two (or multiple) weather systems are approaching, meeting and / or intersecting with each other, intensification produced obviously, that is beneficial to the development of MHRP even while the original systems are weakening. We think that the intensifying actions are induced by so called "Resonance Effect" which can be produced by the conjugation of a number of different weather systems in many places as stated in Sections III–1 and III–2.

The mechanism of resonance effect is not clear enough at present, but it might be: a) resonance of two turbalent systems, b) enhancement of atmospheric baroclinicities, c) resonance of gravitational waves, and d) favourable or enhancement of moisture transportation and / or lower level convergence (positive vorticity) and upper level divergence (negative vorticity) etc.

2. *Plateau Influence*

Numerous cloud clusters are often generated by the topographic dyanmic and thermal

effects over the Tibetan plateau and at the lee-side Southwest Vortexes. These plateau cloud systems are usually moving eastward under the steering flow in westerlies. When they are out-off Tibet and conjugated with other weather systems, some MHRP's and torrential rains can be developed by the connection processes at their downstream. This is one of the major factors why high frequency of heavy rains is around the meiyu front in the area of the Yangtze and Huaihe River Valleys. And it is also one of the major reasons why there are so many intense precipitation processes in the central and eastern China of subtropical zone.

Since most of the MHRP's are produced under the conjugation of various weather systems, by the consideration of combination of synoptical and mesoscale studies, forecasting heavy rains might be promoted, especially for the extended prediction which is urgently needed for the protection of flash flood and hydraulic engineering construction.

REFERENCES

Chen Weimin et al. (1988), *Satellite Pictures*, Nanjing Institute of Meteorology Press, Nanjing.

Chen Weimin (1980), *Satellite Picture Analyses*, Nanjing Institute of Meteorology Press, Nanjing.

He Qing (1987), Inner Mongolia Heavy Rain Occurring at the South of the Shear Line under the "7" Shape High Pattern.

Zhang Yan (1989), Blocking Effect of High Pressure System on the Formation of Extra-intense Heavy Rain, *Acta Meteorologica Sinica* 3(4): 458-470.

Zhang Yan et al. (1990), *Forecasting of Heavy Rain*, China Meteorological Press, Beijing, (in China).

Zhang Yan (1992), Torrential Rain and Severe Floods of the Yangtze and Huaihe Valleys in 1991 and Comparing with the Historicals, International Symposium on Torrential Rain and Flood, Huangshan Mountain, China.

Zhang Yan (1992), Torrential Rains in Tropical Cyclone, ICUS / WMO International Symposium on Tropical Cyclones Disasters, October, 1992.