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Typical Patterns of the Heavy Rains and their Associated Atmospheric Circulation

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The spatial rainfall distributions accompanied by the heavy rainfalls in the Korean peninsula were classified to 6 typical patterns and synoptic characteristics of each pattern were analyzed. 274 cases of heavy rainfall events occurred for 10 years from 1981 through 1990 were used for this study.

In the 4 types of them, heavy rainfalls are not by the strongly developed but by the rapidly deepening low pressure systems, which have a well defined low and high level jets before arrival to the Korean peninsula. In another 2 types, heavy rainfalls are due to specially developed surface low pressure system. Most of the heavy rain areas are associated with the location of the low level jets and their direction and with the position of surface warm front.

In the 4 types, the heavy rain areas extend in zonal direction. And the latitudinal locations of these areas are associated with the polar low center or strong main trough over 500 hPa level. The more northwestern part of the Asia the low locates the higher latitude in the Korean Peninsula the rainfall concentration occurs at. It is also known that the seasonal drifting of the lows have some relations to the progression of summer monsoon but its characteristics change year by year.

1. Introduction

Heavy rainfalls often cause not only the flash floods but also the origin of other disasters. They often cause considerable property of damage and loss of life. Therefore there have been many studies on them. But most part of them are the meso or micro scale case studies (Byun et al : 1992, 1993) by the use of various kind of data. And the other large part of them is the numerical experiments of the rainfall distribution on a particular cases or rainfall processe on the cloud physics. But, it is also more important to understand them on the view point of synoptic climatology for the prediction against the disasters. There have been some studies on this view point but not so much.

The first kind of them are on the pattern classification. For example, Winkler and Charba(1990) focused attention on the sub-synoptic patterns present in observed atmospheric fields such as surface pressure. Konrad II (1993) also hase interests on the synoptic climatology of the heavy rains and focused on the warm air advection patterns over the Appalachian region. Kunkel et al. (1992) focused on the temporal and spatial characteristics of heavy precipitation and next Kunkel et al.(1993) also did on the upper air flow patterns associated with heavy precipitation. Maddox et al. (1979) investigated the synoptic and meso-scale aspects of flush flood events. But all of these studies are about the heavy rains of North American area. In Korean area, Seo et al.(1973) tried to classify the weather charts of heavy rain days.

The second kind of them are on the use of new classification technique. Barthel et al.(1993) analyzed air mass modification by the use of synoptic classification. Kalkstein et al. (1990, 1993) tried to detect the climatic change by the synoptic climatological approach.

In this study, at first, the spatial distributions of rainfall amounts on the heavy precipitation days will be classified, and their associated atmospheric circulation, which are the surface and 500 hPa pressure pattern, 850hPa and 250hPa wind velocity pattern, will be compared each other. Because the classification of Seo et al.(1973) was done by man's physical hand, new objective technique, and new result with recent data are thought to be in need. Heavy rainfall means that there are much rainfall amounts at a time. But There are no quantitative definitions.

Korean Meteorological Agency makes heavy rain warning when it rains more then 150mm for 24 hours. But the 73rd Weather Group of Korean Air Force does when it rains more then 60mm for 6 hours or 130mm for 24 hours. In this study,

Table 1. Representative days and their groups of 6 typical heavy rain patterns with pattern correlation coefficients

yymmdd	yymmdd	coef.	yymmdd	yymmdd	coef
(a) type				890708	0.84
900723	900902	0.80		810625	0.83
	870728	0.77		860616	0.79
	880722	0.71		810711	0.77
(b) type				820813	0.77
840901	900911	0.85		840826	0.77
	900910	0.85		850505	0.76
	810831	0.85		860624	0.72
	840824	0.78		850506	0.71
	851012	0.76		850902	0.71
	840703	0.74	(e) type		
	870721	0.71	800927	880726	0.87
	810701	0.71		850627	0.86
(c) type				900701	0.83
890914	870722	0.82		850705	0.82
	850707	0.77		850626	0.76
	870829	0.75	(f) type		
	870726	0.74	890803	880925	0.89
(d) type				820827	0.79
850623	820723	0.93		860821	0.72
	850624	0.87			

heavy rainfall defined as the rainfall amounts more then 100mm a day as Byun et al.(1992).

2. Data and analysis

1) All available daily rainfall data of the Korean main meteorological stations which have no missing periods from 1981 through 1990 were used. The numbers of stations were 95. In them, 10 stations' data were made by the 73rd Weather Group of Korean Air Force and 25 by the North Korean.

2) For synoptic analysis, the octagonal data from National Meteorological Center were used.

3) The days when there were 3 or more stations of heavy precipitation were selected as a heavy rain case.

4) The distributions of rainfall amounts of selected cases were classified by the map typing method by Lund(1963). The cases that have the correlation coefficient of 0.7 or more classified as one group.

5) Groups that have more then 4 cases were selected and nominated as a type.

6) The composite charts of each type on the sea level pressure, 500hPa geopotential height and wind speed of 850 and 250 hPa level were analyzed and compared each other.

3. Results

3.1 Typical patterns on the rainfall distribution.

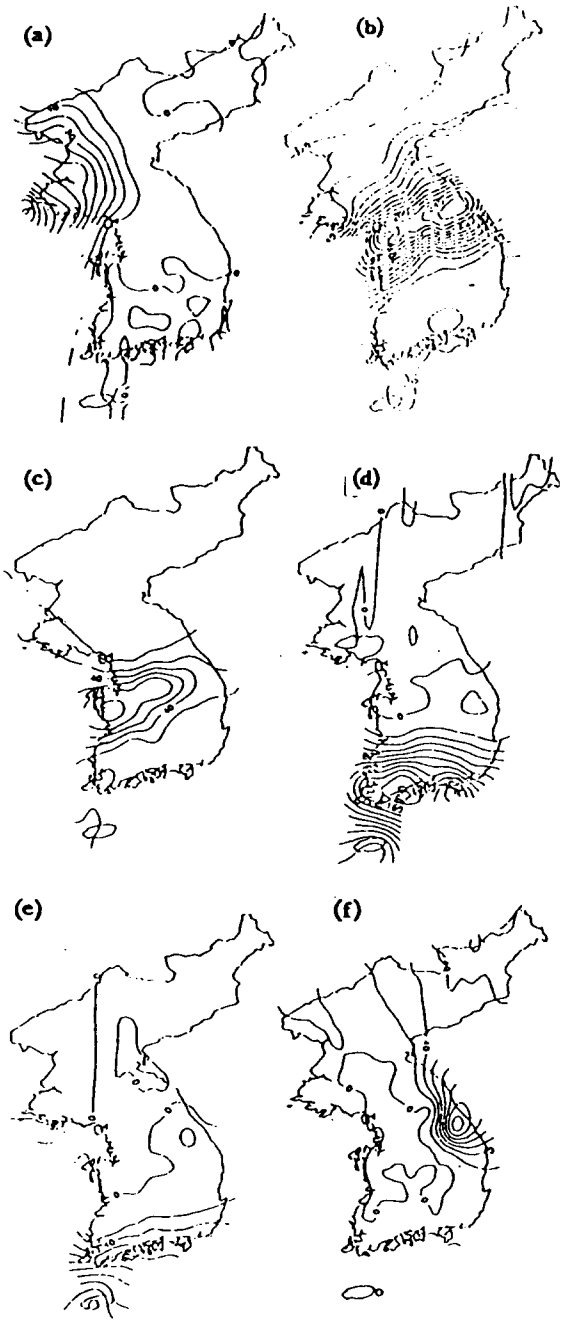

Fig. 1. Representative spatial distribution of the rainfall amounts of each type. Contour interval is 20 mm.

274 days, which have one or more stations of heavy precipitation were detected as the heavy rainfall days. For the elimination of the days with the regional rain-shower, the days that have 3 or more stations of heavy precipitation were selected. Then 119 cases were selected again. After classification of the cases by the method of Lund

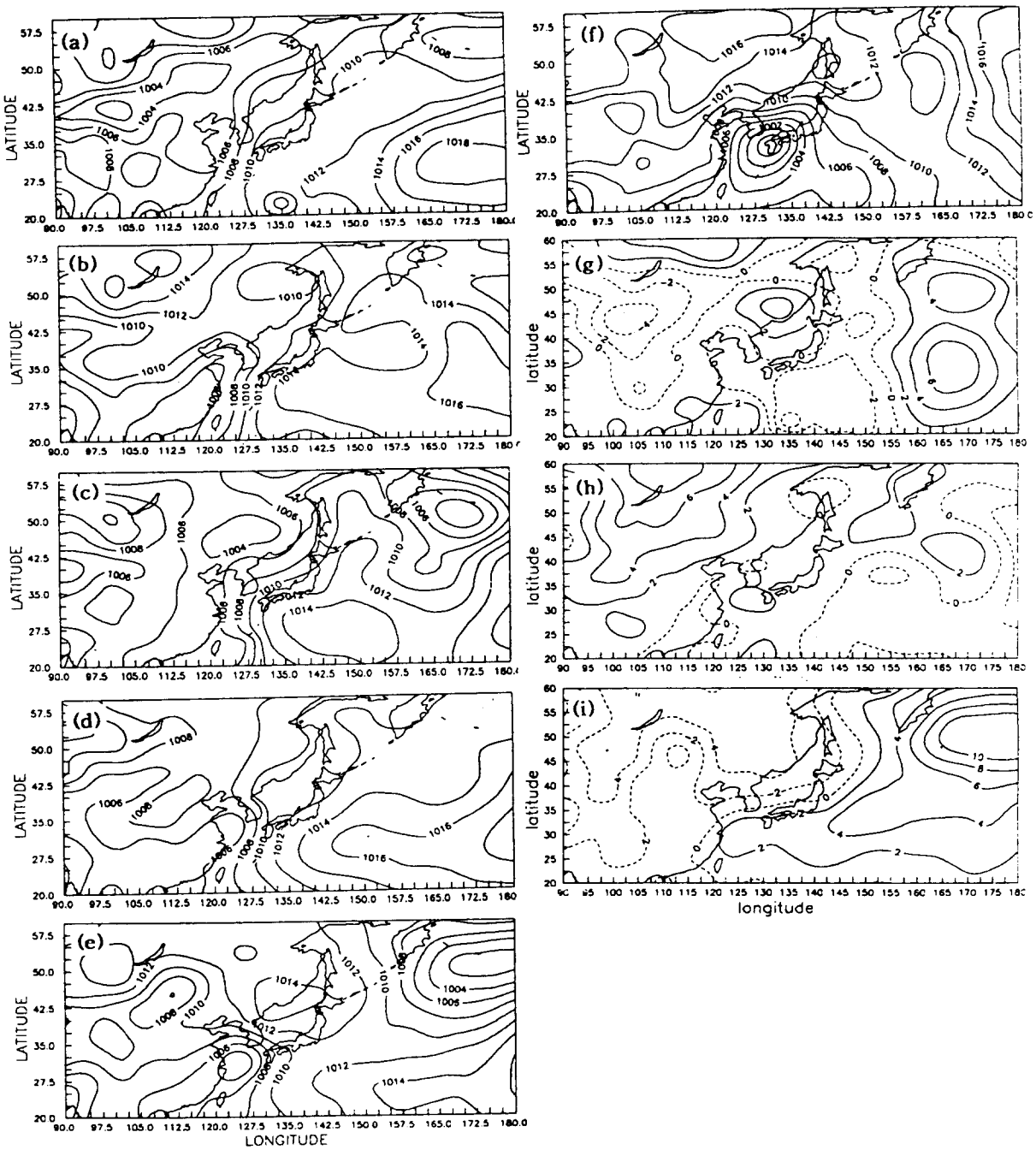

Fig. 2. Composite chart of sea level pressure fields of each types (from a through f). And (g)is deviation chart from (a)type to (c), (h)is from (b)type to (d), and I is from (d) type to (e).

(1963), 6 typical patterns were defined as Table 1.

Fig. 1 reveals the spatial distribution of the rainfall amounts of each type. (a) type reveals the rainfall concentrated near Paek-Yeong island. (b) type does near In-Cheon. (c) type near Seo-San of Chung-Cheong province. (d) type near Keo-Jae island. (e) type near Jae-Ju island. and (f) type reveals the concentration near Kang-Nung of East coast.

3.2 Heavy rainfalls with the surface low pressure systems

3.2.1 With the low pressure systems from China

Fig. 2 shows the composite chart of sea level

pressure fields on each of 6 types. Types (b), (d), and (e) are showing similar patterns to each other on the view point of that the heavy rainfall phenomena were brought about by the low pressure systems approaching from middle or southern part of China. And this heavy precipitation area, as pointed out by the Byun et al.(1993), is suspected to locate at the just north to the warm front of surface low pressure system. These are the most frequent styles of the heavy precipitation in the Korean Peninsula. Especially, (d) type is appearing more then once a year.

In comparing these types, three meanings are coming out. Firstly, it is known that the higher latitude of the surface low pressure center is the more northern part of the Peninsula the heavy precipitation occurs at. Secondly, (b) type occurs at the middle of the summer but (d) type and (e) type occur at the early or late summer. This is known from the fact that a wide positive area in (h) and negative area in (i) over Asian inland, which means the lowest pressure systems occurr at type (d). Also in (i), (d) type occurrs with the strong development of high pressure system over North Pacific.

Thirdly, it is noticeable that types (b) and (d) are the cases of heavy precipitation by the rapid developing low pressure system over the Yellow Sea. It is just like the case investigated by Byun et al. (1993). But in (e) type, the low pressure system was developed strongly already before the arrival to the Korean peninsula.

3.2.2 With the low pressure systems passing the Manchurian plain

In types (a) and (c), there are no approaching centers of the low pressure systems in Fig. 2. Main low pressure systems are over the Manchurian plain and only a trough extended form them are approaching to the Peninsula. This style of heavy precipitation is very difficult to predict. But some symptoms are there as explained in next chapter. One difference of (a) from (c) is the positive deviation area over the East Sea and the North Pacific, which is in (g). By the comparison with the table 1, it is known that (a) type occur at the middle of summer like (d) type, but (c) type is unclear.

3.2.3 With low pressure center over the Kyushu

(f) type has big differences from all other types. It looks like that the easterly current induced by the low pressure system over the Kyushu of

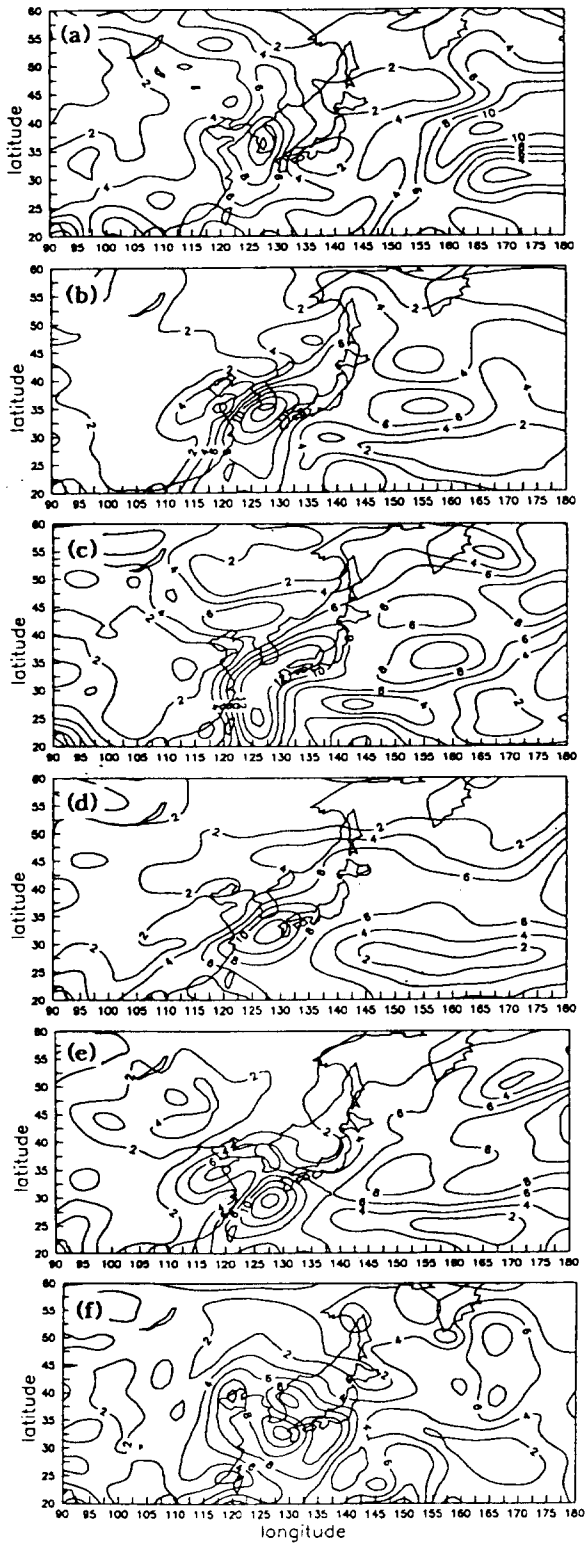

Fig. 3. As in Fig. 2 but for 850 hPa level wind speed.

Japan made heavy precipitation at the upwind side of mountainous area of the Peninsula. Then rainfall distribution stretched not zonally but meridionally and most of heavy rains concentrated on the east of the Tae-Baek (backbone mountains of the Peninsula)

3.3 With the low level jets

Fig. 3 shows the composited isotachs of 850 hPa level. All types show the existence of the low level jet. They are clearer appearance than sea level low pressure systems and it means that it can become a good index, which can say the developing of heavy rain system. All of the low level jets are located at the warm sector and at the south or southeast part of sea level low pressure system.

In (a) type, the meridional flow is dominant and it looks like that this flow made the rainy area move to the north. In all types except (f), heavy rain area located not under the area of maximum wind but under the area of the severe gradient of wind speed. In (f) type, it is known that the rotating flow around the strong low pressure system becomes stronger at the upwind side of the mountains.

3.4 With the upper level jet

Fig. 4 shows the composited chart of 250hPa isotachs each type. Firstly, except (f) type, the higher latitude the heavy rain area is the higher latitude the jet stream is located on. Secondly, in types of (a), (b), (c), and (d) upper level jets are located north to the heavy rain area. Thirdly, heavy rains occur at the area of the big gradient of wind speed around jet core. Fourthly, the nearer location of jet core to the Peninsula shows the more possibility of the rapid development of the approaching low pressure systems, which can be seen from (b) and (c). This can be the clearer symptom of the occurrence of heavy rainfalls than sea level troughs or low level jets. Fifthly, the directions of the isotachs over the Korean Peninsula are similar to the direction of the main axis of heavy rain area in all types except (f) type.

3.5 With the Arctic low in the middle troposphere

Fig. 5 shows the composited geopotential height field of 500 hPa level. The center of Arctic low or centric trough from it is located over the Mongolia in the (a) type, and over the northern part of the Sea of Ohkotsk in (b) type, over the Kamchatka

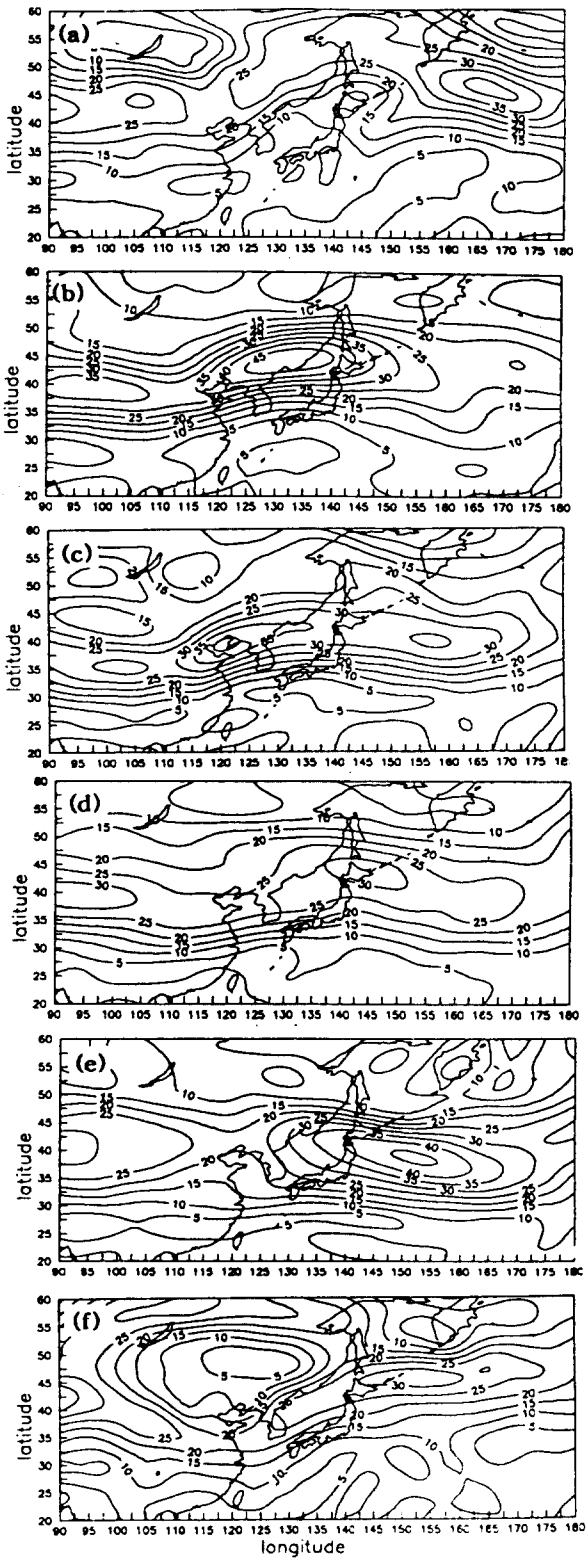

Fig. 4. As in Fig. 2 but for 250 hPa level wind speed.

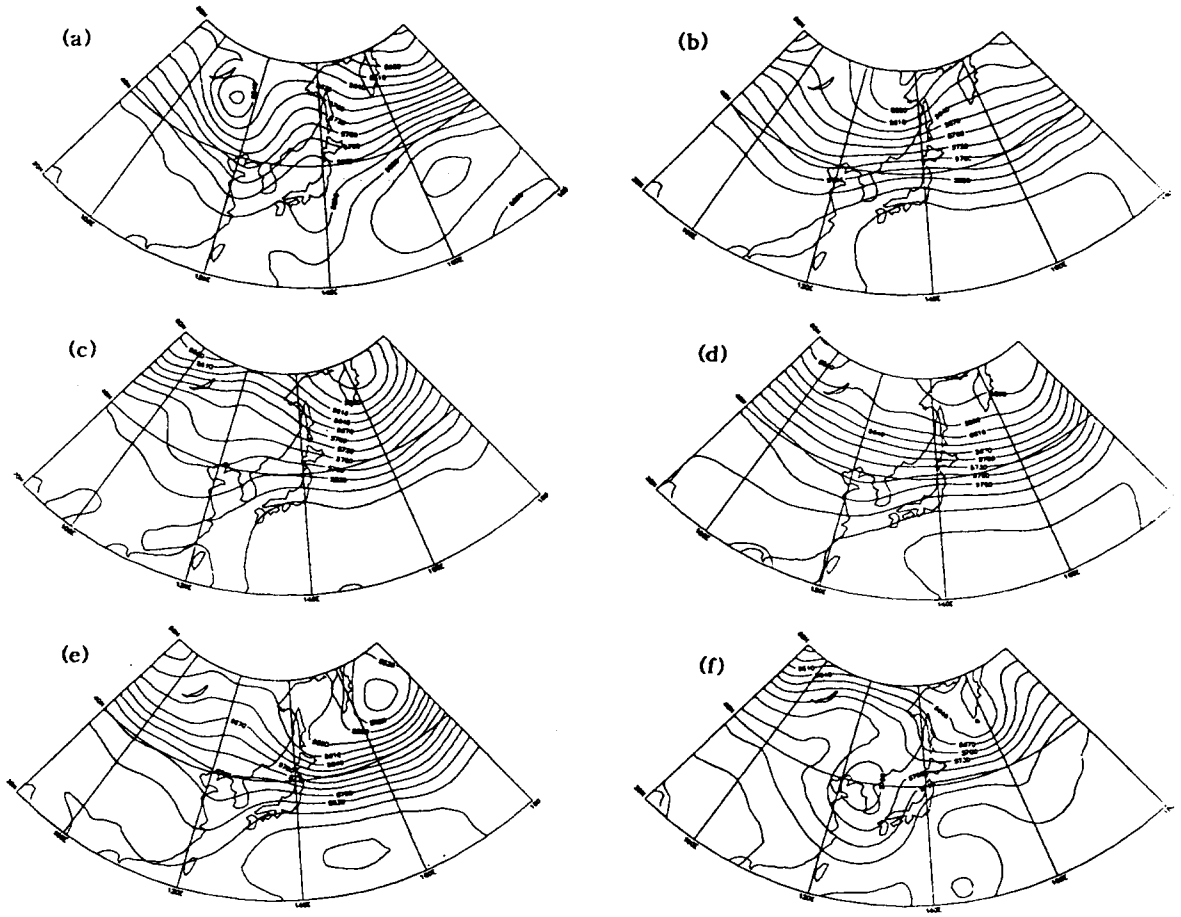

Fig. 5. As in Fig. 2 but for 500 hPa level geopotential height.

peninsula in (c) type, over the northern part of the Bering sea in the (d) type, over the Aleutian islands in the (e) type. It tells that the higher latitude of the heavy rain area is, the more western part in the Asia the center of the arctic low pressure system or centric trough from it is located. This seems to be due to the effect of steering current to the heavy rain system from the Arctic low center and can be used as a tool for the prediction of heavy rain area too. And one another important characteristic is that at all of five types, south westerly current is dominant in the Peninsula.

4. Summarizing discussion

1) In typical cases, the heavy rain occurs north to the sea level warm front and south to the upper level jet with the big gradient of wind speed. The latitude of heavy rain area decided, at first, by the location of Arctic low pressure center at 500 hPa level, and next, another parameters just like location of the subtropical high pressure system, the strength of the meridional part of the low level jet and the direction of the sea level trough etc.

2) Most of heavy rains occur with the rapidly developing surface low pressure systems over the Yellow Sea. In those cases low level jet appears at the warm sector of the systems before developing, and/or upper jet cores appears just near the systems. And these two can become a good index to detect the activity of the low.

3) The main axes of heavy rain areas have the same direction to isotachs of the upper level jet.

4) Special characteristics on upper level jets in type (e) and (f) are noticeable for further research.

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전형적인 호우와 연관된 대기순환

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1981년부터 1990년까지 10년간 발생한 274개의 호우사례를 분류하여, 한반도에서 호우시에 나타나는 강수량의 공간분포를 여섯 종류로 나누고 각각의 종관적 특성을 분석하였다.

첫째, 강하게 발달한 지표 저기압에 연관되어 발생하는 호우보다 상, 하층 제트를 동반한 채 발달중인 저기압에 연관되어 발생하는 호우가 많다. 둘째, 대부분의 호우역은 하층 제트의 위치와 방향 그리고 지표 온난전선의 위치에 연관되어 있다. 셋째, 500hPa 면의 저기압 중심이나 기압골의 위치가 서쪽으로 멀어질수록 한반도에서의 호우는 고위도에서 발생하는 경향이 있다. 넷째, 한반도에 호우를 초래하는 500hPa의 저기압 중심은 하계몬순의 발달을 따라 서쪽으로 자리잡는 경향이 있으나 해마다 차이가 있다.