

ORIGINAL ARTICLE

A Study of Convective Band with Heavy Rainfall Occurred in Honam Region

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Abstract

On the study of the characteristics and life cycle of mesoscale convective band in type of airmass that occurred in the Honam area from June to September for only 4 years in the period of 2009~2012, 10 examples based on the amount of rainfall with AWS 24 hours/60 minutes rainfalls, Mt. Osung radar 1.5 km CAPPI/X-SECT images and KLAPS data for convective band with heavy rainfall event were selected. There were analyzed and classified by using the convective band with heavy rainfall occurred along the convergence line of sea wind in the form of individual multi-cellular cell and moving direction of convective band appeared in a variety of patterns; toward southwestern (2 cases), northeastern (4 cases), congesting (2 cases), and changing its moving direction (2 cases). The case study dated of the 17th Aug. 2012 was chosen and implemented by sequentially different evolution of its shape along the convergence line of sea wind cell and moving direction of convective band as equivalent potential temperatures at the lower layer have increased to the upper layer 500 hPa, that the individual cells were developed vertically and horizontally through their merger, but owing to divergence caused by weakened rainfall and descending air current, the growth of new cell was inhibited resulting in dissipation of convective cells.

Key words : Convergence, Rainfall, Convective band, Life cycle, Equivalent potential temperature

1. Introduction

Torrential rain generally means the rainfall when its volume amounts to at least 30 mm per day or 10 % of annual precipitation during a day. This is accompanied by typhoon, Changma front, well-developed low pressure, etc. but sometimes appears caused by MCS (Mesoscale Convective System). Parker and Johnson (2000) classified Linear MCS into TS (Trailing Stratiform) type, LS (Leading Stratiform) type and PS (Parallel Stratiform) type according to the life cycle of mesoscale convective system. Choi et al., (2011) classified torrential rain

into Changma front type, low pressure type, typhoon type and North Pacific high type. Lee and Kim (2007) classified heavy rainfall system occurring in the Korean peninsula into IS (Isolated thunderstorm) type, CB (Convective band) type, SL (Squall line) type and CC (Cloud Cluster) type. Of these, frequency of CB type heavy rainfall system occupies 30 % or more, which is reported to cause a lot of damages as it results in torrential rain in a short time. In addition, CB type is similar to squall line, but is more likely to cause torrential rain in the narrower area than squall line owing to its tendency of moving toward longitudinal direction of torrential rain or staying in

Received 14 December, 2014; **Revised** 16 March, 2015;

Accepted 20 March, 2015

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that area (Lee and Kim, 2007).

Honam area is easy for the sea wind to converge in the daytime in western and southern seas. According to the numerical experiment of Sun and Lee (2002), it showed the feature of convective band being formed following the development of heavy rainfall cells, its movement along the mean flow, formation of convergence line at the lower layer at the wind and front of the place where heavy rainfall cells occurred resulting in the development/maintenance of new heavy rainfall cells. Yang and Ryu (2002) reported that heavy rainfall during non-rainy season is mainly caused by microphysics, which arises from a deep cumuliform cloud. Single cell storm is the typical storm that has a single ascending air current and short life cycle. On the contrary, the multi-cellular cell storm consists of the group of single cell storm new cells of which are formed from convergence arising from descending air current (Browning et al., 1976; Weisman and Klemp, 1986; Chung et al., 2013). Mesoscale Convective System is the complex constituents of a single cell which carries a certain period of life repeating development and dissipation. Such convective band with heavy rainfall is the Mesoscale Convective System that quickly develops itself and grows resulting in local damages. But it is difficult to forecast, and its phenomenon appears in a complex type.

In this study, to examine the characteristics and life cycle of convective band that occurred in the Honam area, the examples of convective band with heavy rainfall event and the properties of the life cycle from occurrence to dissipation as well as mesoscale environment when heavy rainfall occurred from the aspect of phenomenon were selected.

2. Data and Analysis method

10 examples of convective bands that occurred in the heavy rainfall observation period (June through September) during the period of four years (2009~

2012) were selected based on AWS data of 24 hours/60 minutes rainfalls which were collected only if the precipitation was at least 30mm in the area of highest rainfall per hour on the day when the horizontal length of rainfall (Strength of rainfall showing 1mm of hourly rainfall in the radar image) that corresponds with the definition of convective band with heavy rainfall was at least within 100 km. Rainfall analysis was made using AWS observation data. In case of rainfall distribution map, mainly rainfall movement and strength was examined using rainfall data after 15 minutes, 1 hour, and 24 hours, respectively. In addition the observation data of an area was analyzed using time series graph while the type of air current on the ground was used by wind vector data. Comparisons to analysis of the data of convergence were conducted with air current directions indicated in the wind vector. Strength and property of convective band were grasped using Mt. Osung radar 1.5 km CAPPI data. In addition, 10- minute interval dBZ data was adopted using X-SECT that displays the cross section of horizontal image at Mt. Osung vertically. Furthermore mesoscale data supplementing the vertical data of radar was adopted using KLAPS (Korea Local Analysis and Prediction System) that is the very short range weather analysis and forecast system. The characteristic of convective band with heavy rainfall in occurrence stage, development stage, mature stage and dissipating stage in terms of life cycle was suggested centered on the example dated of the 17th August 2012 when the life cycle property was very remarkable using mesoscale data.

3. Result and Discussion

3.1. General characteristic of convective band

Convective band with heavy rainfall occurring in the Honam area appeared along the convergence line of sea wind in the form of individual multi-cellular cell. It formed its shape mainly in its development

Table 1. CB (Convective band) cases and their characteristics

Occurrence time	Shape	Direction of movement	Areas / 1-hour maximum rainfall
1600LST 05 Jul 2009.	broken line type → oval type	SW	Sunchang / 33.5
1500LST 26 Jul 2009.	broken line type	NE	Eyang / 41
1500LST 27 Jul 2009.	line type	stagnation	Sunchang / 68
1700LST 30 Jul 2009.	line type → oval type	NE → SW	Dado / 27
1400LST 06 Jun 2010.	line type → oval type	SW → NW	Gwangsan / 49
1200LST 03 Aug 2010.	freestyle (Distributed type)	NE	Gangjin / 40
1300LST 14 Aug 2011.	freestyle (Distributed type)	NE	Mt. Moak / 38.5
1600LST 17 Sep 2011.	line type	stagnation	Juam / 70
1400LST 06 Aug 2012.	broken line type	SW	Gangjin / 46
1500LST 17 Aug 2012.	line type	NE	Jeonju / 36

stage.

The type of convective band appeared in four kinds as shown in the Fig. 1 Bluestein and Jain(1985) classified the linear MCS into Broken line, Back

building, Broken areal and Embedded Areal. These formed themselves mainly in the development stage. In case of line (a), individual convective cells appeared in a low extending themselves vertically and horizontally

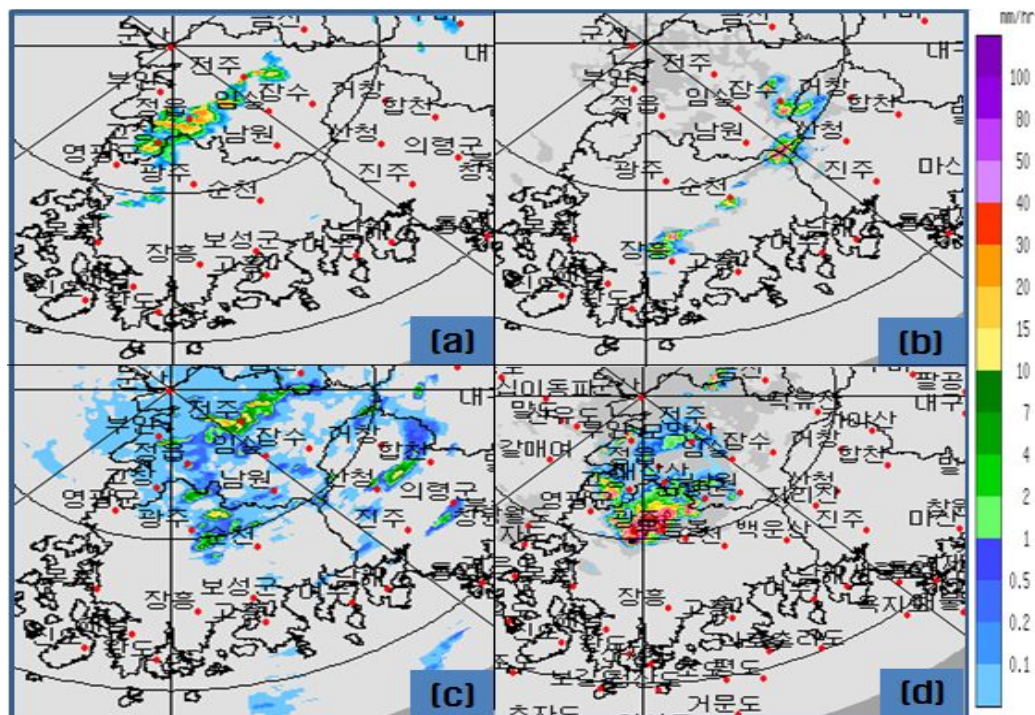


Fig. 1. The main types of convective band at the developing stage. (a) line type (22 LST 17 Aug 2012), (b) broken line type (20 LST 26 Jul 2009), (c) free type (16 LST 14 Aug 2011), and (d) oval type (17 LST 6 Jun 2010).

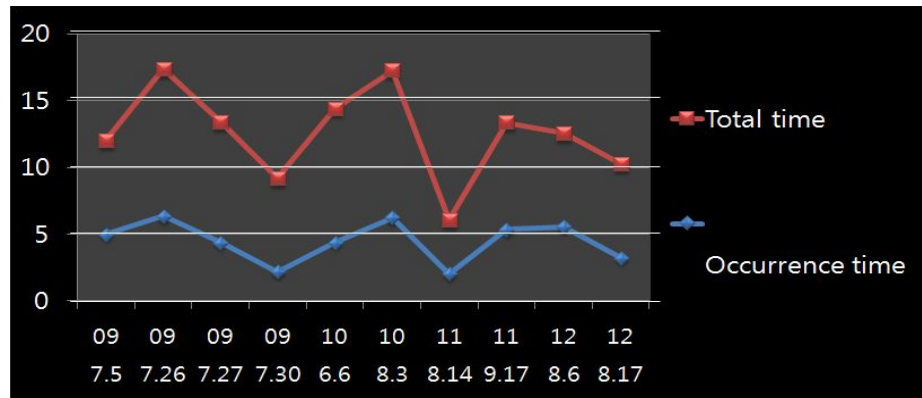


Fig. 2. The relationship between total time of convective band and time occurred heavy rain. (y-axis : time, x-axis : date of case).

in the development process of such cells, which are connected together by merger of cell. Broken line type of (b) is developed with convective cells with interval, which is broken without connection in spite of horizontal expansion. In case of (c), as the velocity of air current is so quick, its echo moves quickly together with speedy air current resulting in the formation of linear form in part although it fails to form its particular form on the whole. In case of oval type of (d), it moves to a single direction in the linear form, but echo appears in the form of oval type as the moving direction of echo is changed. When convective band reaches mature stage, the most remarkable phenomenon is the occurrence of heavy rainfall.

Sometimes the rainfall amounting to 30 mm per hour appears. Most of convective cells undergoes sufficient development stage since its occurrence. The times taken to reach mature stage were varied depending on individual example. Fig. 2 shows the time in time series taken for convective cells until the generation of heavy rainfall during its life cycle from occurrence stage until dissipating stage. Total life cycle of convective band was found to be 4~11 hours. The time when heavy rainfall (accumulated rainfall at maximum per hour) occurred was 2 hours 20 minutes ~ 6 hours 35 minutes after the occurrence of convective

band. Except a single example, most of them occurred at the middle end after the occurrence of convective band. This represents that echo developed through cell merge in its development stage is developed to the maximum in the mature stage after its development stage when the max. rainfall appears. In addition, at the time of mature stage when the whole period of convective cells is long, the time that heavy rainfall occurs gets longer, and as the whole period is short, the time that highest precipitation occurs is short.

3.2. Convective band in initial stage on 17 Aug 2012

Convective band occurred in Honam area was found similar to the classification of Bluestein and Jain (1985), was the four types of primitives are line type. The purpose of this study is to analyze focused 17th Aug. 2012 of the 10 line types. Mesoscale characteristic of temperature distribution during convective band occurrence stage is the appearance of warm pool on the inland area owing to convergence of sea wind when the highest temperature occurs and the formation of the convergence line showing the ground air current is converged as the inland area becomes to thermal low. According to the Fig.3 (a)~(d), at the time of highest temperature, there appeared relatively cold pool near the mountain range, while warm pool

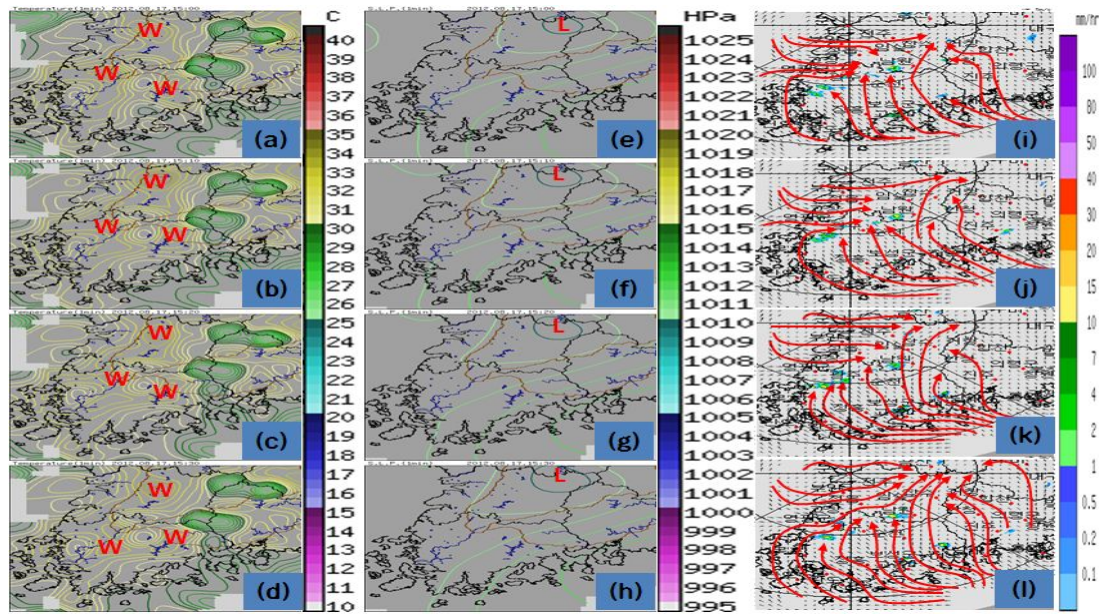


Fig. 3. (a), (b), (c), (d) :The temperature distribution at the 1500, 1510, 1520, and 1530 LST 17 Aug 2012. (e), (f), (g), (h) : The pressure distribution at the same time. (i), (j), (k), (l) : surface air flow and CAPPI reflectivity at 1.5 km at Mt. Osung (surface wind vector : small black arrow, and surface air flow : red arrow) at the same time.

near the plain. In the (e)~(h), sea-level pressure was shown in low pressure centers in the southern and northern parts toward the inland area of the Honam district. Sea wind brew from the ocean to the land where sea wind is converged toward the center of thermal low pressure of the inland area. At the time when convective band occurred, the highest temperature is formed in the inland area and relatively low pressure is formed owing to temperature in the Sobaek Mountains and the ocean because of relatively low temperature. In case of initial convective cells constituting convective band, the convergence line is formed as shown in (i)~(l), and accordingly convective cell occurs along the convergence line.

According to the Fig. 4(a)~(c), rainfall shows relatively weakness with 1~2 mm/15 min or less in its occurrence stage. Even in the horizontal radar data of (d)~(g), it shows relatively low reflectivity amounting to 20~25 dBZ. According to (h)~(k) that is the X-sector

image in the occurrence stage, convective cells occurs and is developed in the south western area of Gwangju. At 1530 LST, cloud top is developed up to 7~8 km, and vertical reflectivity amounts up to 40 dBZ at maximum. In Sancheong and Suncheon, however, is shown as an empty space where no echo occurs.

Fig.5(a) is the image representing 80 % or more of horizontal wind, Equivalent Potential Temperature (EPT), and relative humidity. Between Mokpo and Yeonggwang, the maximum EPT in the value of 366 K appears. At least 80 % of humid zone appears at the lower layer, which is deemed to be high humid zone formed in the convergence area of sea wind. EPT concentrated area appears at the place where convective cell occurs, and 340 K EPT line is distributed near 800 hPa height over the humid zone. Relatively low EPT (332~336 K) is formed in the 850~500 hPa zone.

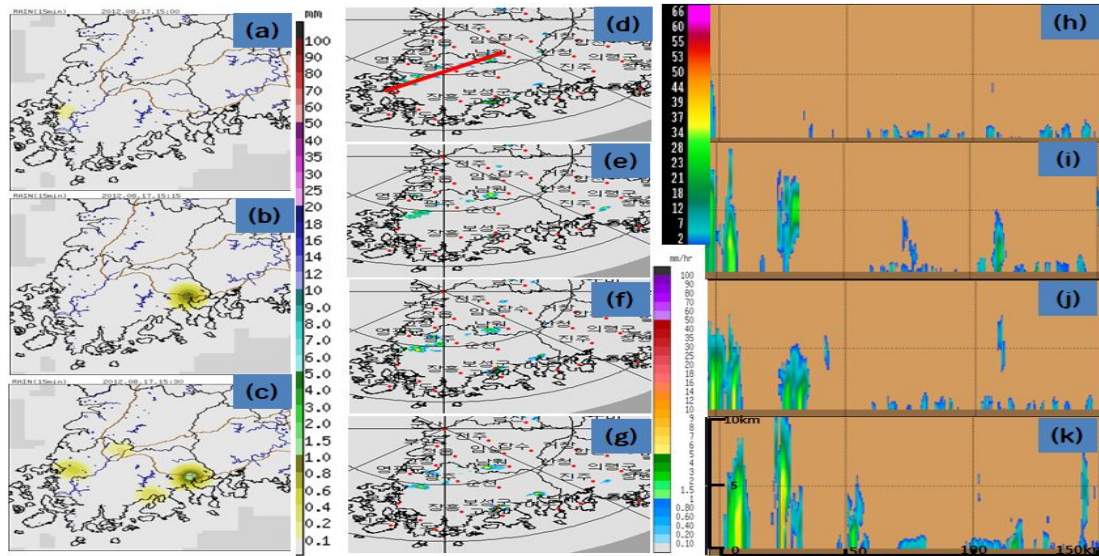


Fig. 4. (a), (b), (c) : AWS precipitation at the 1500, 1515, and 1530 LST 17 Aug 2012. (d), (e), (f), (g) : The RADAR product of CAPPI images at 1.5 km elevation in Mt. osung 1500, 1510, 1520, and 1530 LST. (h), (i), (j), (k) : RADAR product of X-sector at the same time.

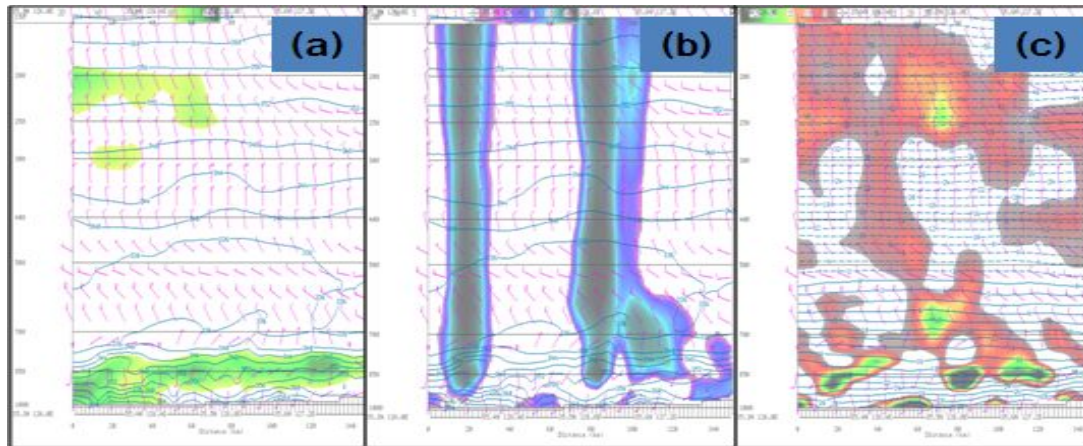


Fig. 5. KLAPS images (KLAPS vertical cross section images at 35.3 N, 126.3 E, 36.1 N, 127.5 E. 15 LST 17 Aug 2012). (a) horizontal wind (knot unit, vector arrow), EPT (K unit, blue line, relative humidity of more than 80 %), (b) horizontal wind (knot unit, vector arrow), EPT (K unit, blue solid line), omega (updraft with shading based on the scale at top). (c) horizontal wind (knot unit), temperature (the blue solid line : °C unit), convergence (represented with shading based on the scale at top).

3.3. Convective band in development stage

The outstanding characteristic of temperature distribution in development stage is the drop of temperature in the inland area. According to the Fig. 6(b), cold

pool is expanded in the center of the inland area in the southern part of Jeonbuk and northern part of Jeonnam at 1700 LST. In 10-minute unit, it shows the style of cold pools in the eastern and western part

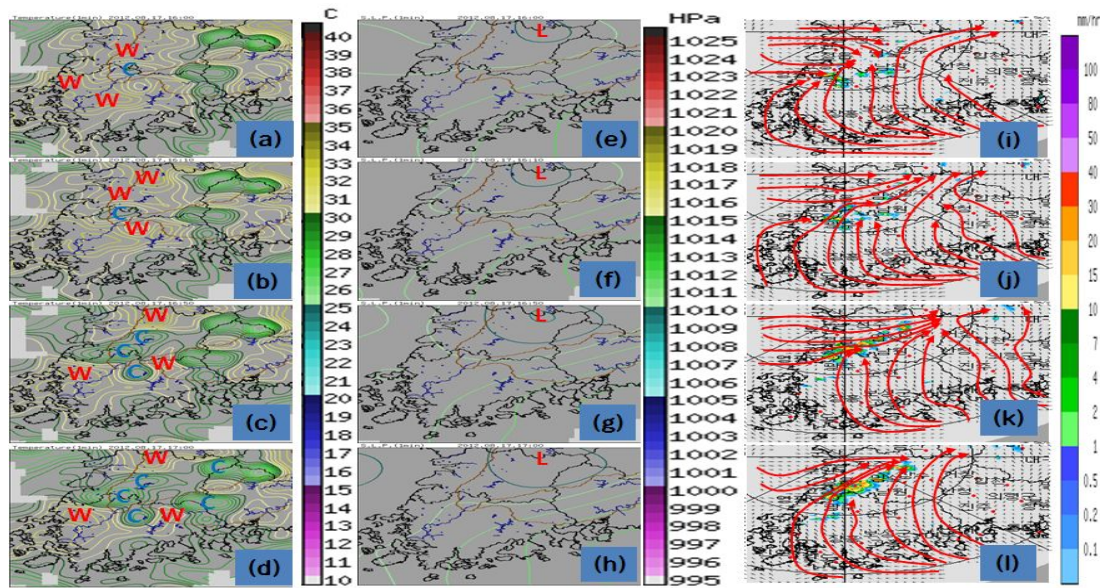


Fig. 6. The same as Fig. 1, but for at (a, e, i), (b, f, j), (c, g, k), (d, h, i) : 1600, 1610, 1650, and 1700 LST.

being connected together. As the temperature drops, the pressure pattern formed in north-south pressure trough in the Honam area as shown in (e)~(h) appears to be high pressure ridge toward the inland area of Jeonnam as shown in (g). According to (i)~(l), air current convergence increases caused by increase in pressure gradient force resulting in a long convergence of air current as it directs from (k) to (l). Air current at development stage varies from occurrence stage owing to changes in temperature and pressure.

According to the Fig. 7(h)~(k), at the same time as convective cells is developed, individual cells undergo the process of development in size and strength through their merger. Lee et al, (1993) reported that wind merger could be analyzed through satellite and radar, which is important for the formation of large convective wind, while Westcott and Kennedy (1989) reported that the combined system gets larger than isolated system, continues longer, and causes larger amount of rain. In (a)~(c), precipitation of the combined convective cells keeps increasing. Convective cells separated g) and its reflectivity increases in horizontal

and vertical manners.

In the Fig. 8(a), in the occurrence stage, low EPT (334 K) was shown at the height of 850 hPa but at 1600 LST EPT 340K line moves to upper layer until 500 hPa. This represents that the cloud zone is developed up to middle atmosphere as convective cells are combined together. In (b), as high EPT area moves to middle atmosphere, ascending air current region located near the ground (red dotted line) shows a strong ascending air current from lower layer to middle layer along the high EPT area (340 K). That is, as the velocity of ascending air current on the ground gets strong, it creates the environment where convective cloud can be developed in a vertical manner. In addition, the wind of south wind series appears in the high EPT area while the west wind series in the low EPT area. In (c), convergence starts to place itself at 700~500 hPa that is the atmosphere middle layer. On the contrary, change in temperature doesn't appear greatly on the ground and at the upper layer.

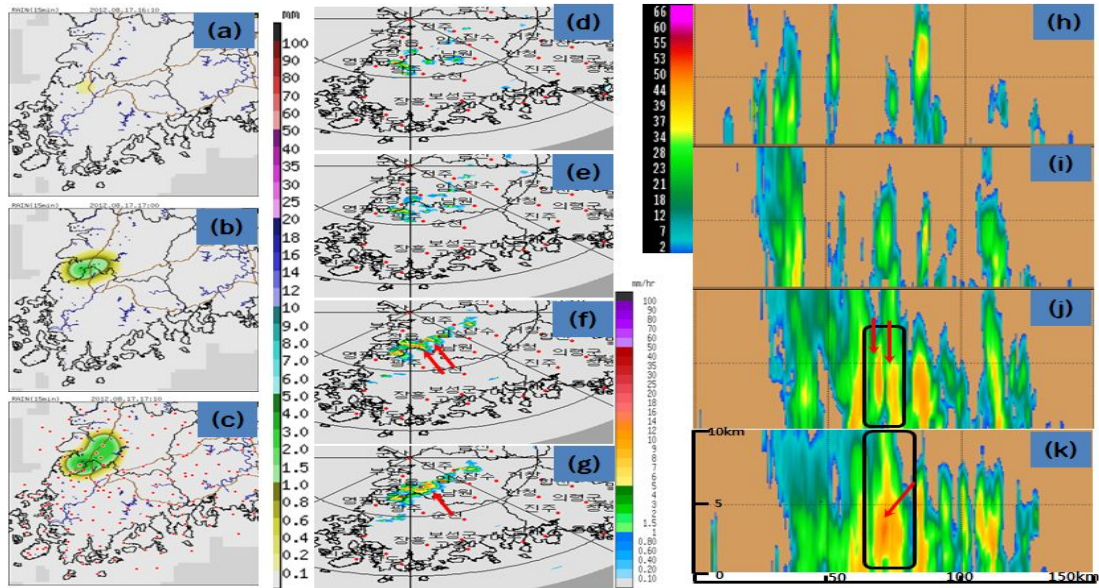


Fig. 7. The same as Fig. 4, but for at (a, b, c) : 1610, 1700, and 1710 LST, (d, h), (e, i), (f, j), (g, k) : 1600, 1610, 1650, and 1700 LST.

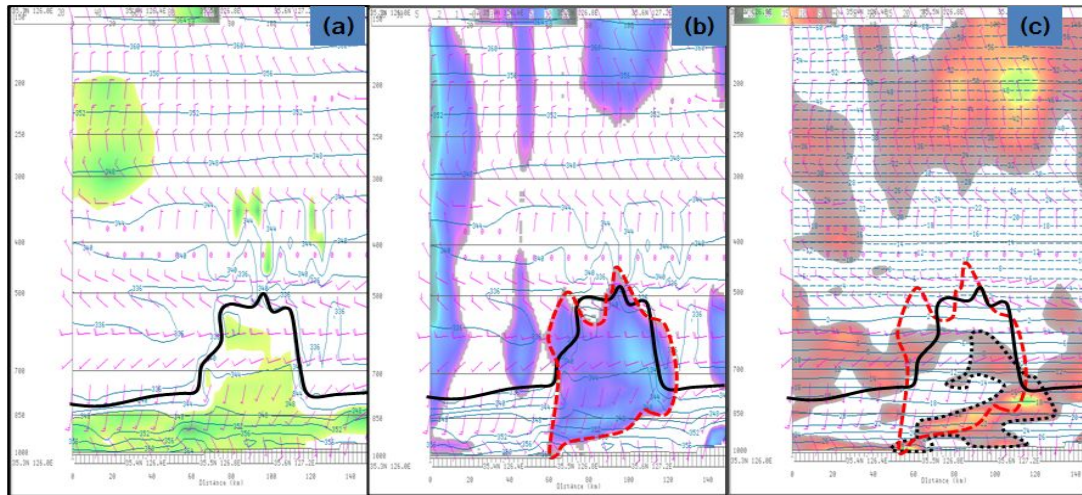


Fig. 8. The same as Fig. 3, but for at (a, b, c) : 1600 LST (black solid line-340 K EPT, red dotted line- Ω , black dotted line-convergence).

3.4. characteristic of convective band in mature stage

Convective band mature stage is characterized with the occurrence of maximum rainfall resulting in descending air current and formation of new cells in front caused by a strong descending air current. Black

arrows in (a), (b) and (c) of Fig. 9 represent between Gochang and Namwon in (e) gradually develops itself in (f), which is combined in descending air current that occurred by the rainfall of convective cells. During development stage, converged air current only existed

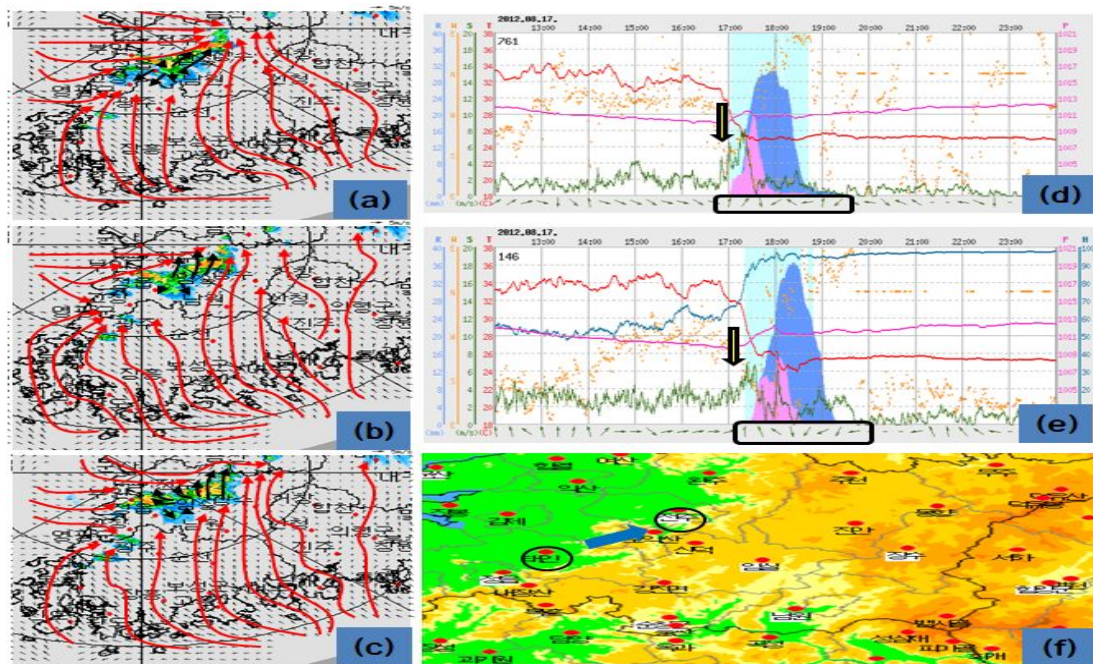


Fig. 9. (a), (b), (c) : Air flow and the RADAR images 1730, 1740, and 1750 LST. (d), (e) : The time series of the AWS data at Taein, Jeonju, (f) : Location of Taein, Jeonju and movement direction of convective band (blue dotted arrow represents moving direction).

in this area. However, diverged air current was captured near Jeongeup, Imsil, Namwon at 1730 LST on the 17th August 2012. Northwest wind blew up to 1700 LST in Taein of (d). When convective band from approached, the wind was changed into the south wind from 1700 LST, and subsequently the wind speed increased up to 10m/s or more and the temperature suddenly dropped along with the rain. In addition, wind direction was transferred from south toward north-east. Jeong and Ryu (2008) reported that heavy rainfall of north pacific high pressure is shown in southwest series wind immediately before the maximum rainfall on the coastal area, which is a synoptic pattern different from mesoscale pattern. Rainfall recorded 30.5mm per hour. This represents that descending air current caused by heavy rainfall is clear and the wind direction changes as convective cells move. In the (e) Jeonju time series graph, the

similar pattern to Taein appears. Rainfall at 1724~1817 LST also recorded 36mm. According to (f) in terms of geography, there is Jeonju at the northeast part of Taein. Convective cells that approached Taein at 1700 LST moved to the northeastern direction reaching Jeonju after 24 minutes, which suddenly caused the wind by descending air current to turn out together with rainfall. Secondary convergence was formed in front of descending air current resulting in the occurrence of new cell in front of the moving direction of convective band. In the Fig. 10(d), a small cell is formed in the northern part of Jangsu. At the same time, according to vertical radar image in the Fig. 10(g), there occurs N+1st cell at the right end showing vertical feature of newly formed convective cells. Its height is developed up to 6km, and the reflecting strength amounts to 20~40 dBZ. In the Fig. 10(a), convective cells that recorded 14 mm rainfall

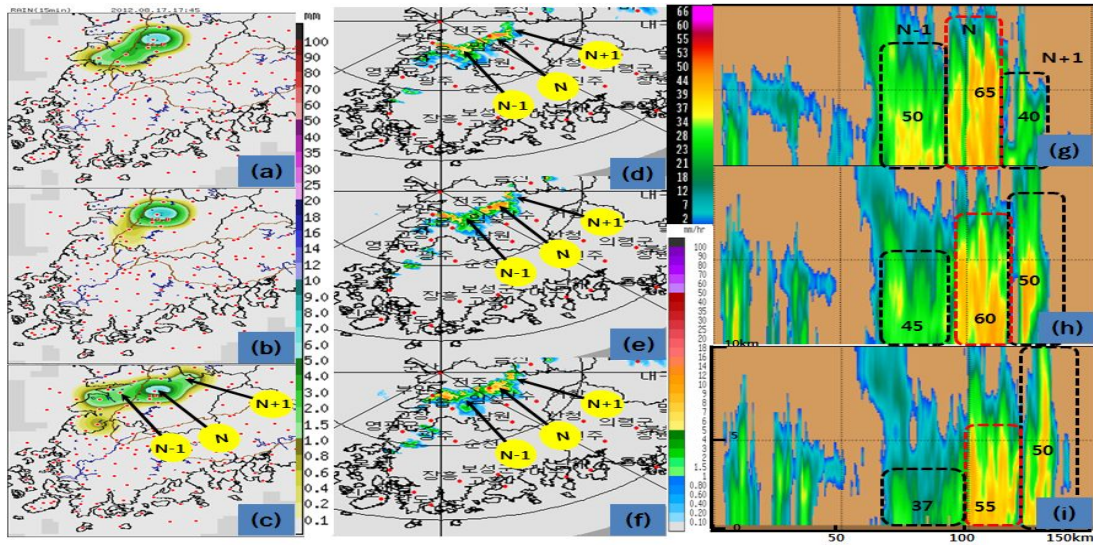


Fig. 10. The same as Fig. 6, but for at (a)1745, (b)1800, and (c)1815 LST, (d, g) 1730, (e, h) 1740, and (f, I) 1750 LST, black arrows represent cell, black, red, and sodomy dotted boxes represent old cell, mature cell, and new cell.

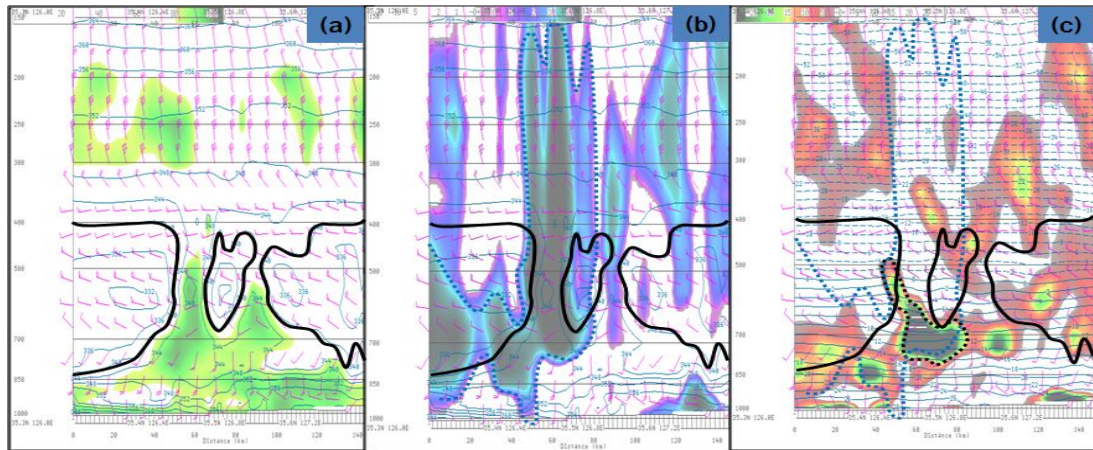


Fig. 11. The same as Fig.3, but for at (a, b, c) : 1800 LST (black solid line-340 K EPT, blue dotted line- Ω , black dotted line-convergence).

in Jeonju area for 15 minutes is the Nth convective cells that is active at moment. This convective cells are in its mature stage, which is developed to 65 dBZ at maximum, and up to the height of at least 10 km. The N-1st cell at its back side is the cell that passed mature stage, which is developed to 50 dBZ and up to the height of at least 10 km showing approx. 5mm

rainfall. After 10 minutes, the N+1st cell in the Fig. 10(h) is suddenly developed showing the reflectivity amounting to 55 dBZ, which is developed to the height of at least 10 km. In case of reflectivity, the Nth convective cells in its mature stage amounts to 60 dBZ showing low degree, while that of the N-1st cell amounts to 45 dBZ showing lower degree. After

10 minutes, the N+1st cell at 1750 LST in the Fig. 10(i) is suddenly developed showing the reflectivity amounting to 50 dBZ developed to the height of at least 10 km. In Jucheon, 2 mm rainfall was observed. On the contrary, reflectivity of the Nth convective cell in its mature stage is weakened to 55 dBZ and the height also dropped to 8~9 km. Rainfall is weakened remarkably to 10 mm. In addition, for the N-1st cell, reflectivity was weakened to 30~37 dBZ while the rainfall suddenly dropped to 1mm or less. Occurrence and development of new cell corresponds with the position of new cell and the strong convergence in the northern part of divergence area that occurred between convergence areas.

Divergence area occurred caused by descending air current that appeared in Jeonju in its mature stage. New cell is deemed to have occurred in front of gust front between its divergence area and the strong convergence area.

In the Fig.11(a~c), the domain of high EPT (340 K) and high humidity area (at least 80 %) reach 500 hPa and high EPT area increased up to 400 hPa at a certain height. As high EPT area (340 K) at upper and lower layers is connected with that at upper layer, low EPT area (332 K) at the atmosphere middle layer (850~500 hPa) was completely separated into left and right sides. In addition, low EPT area is a dry area where northwest air current is distributed. On the contrary, high EPT area shows southwest air current in a narrow district, and high humidity area moves to the upper layer through this narrow channel. That is, atmosphere with potential instability caused by EPT moves the humid area on the ground and lower layer to the upper layer.

Bryan and Fritsch (2000) reported that vertical cross section in the wet convective area of MCS is located at middle atmosphere, high EPT area is located at lower/upper layers of atmosphere, and moist absolutely unstable layer exists in the boundary between high EPT and low EPT area. convective band that

occurred in the Honam also showed vertical structure similar to this in the shape.

4. Conclusion

From June to September for only 4 years in the period of 2009~2012, 10 examples based on the amount of rainfall with AWS 24 hours/60 minutes rainfalls, Mt. Osung Radar 1.5 km CAPPI/X-SECT images and KLAPS data for convective band with heavy rainfall event were selected and analyzed. There have figured out two main parameters such as the convergence line of sea wind in the form of individual multi-cellular cell and the moving direction of convective band appeared in a variety of patterns; toward southwestern (2 cases), northeastern (4 cases), congesting (2 cases), and changing its moving direction (2 cases).

The case study dated of the 17th Aug. 2012 which has been shown the typical characteristics and life cycle of convective band was chosen and implemented among 10 samples.

In the initial stage the multi convective cells have mainly formed its shape along the convergence line of sea wind cell and moving direction of convective band as equivalent potential temperature at the lower layer have increased to the upper layer 500 hPa, that the individual cells were developed vertically and horizontally through their merger in the developing stage, within highest temperature ± 3 hours with pressure gradient force in a weak condition. There didn't yet occur any convergence area at lower layer and middle atmosphere.

In its development stage the convective band showed a certain forms such as line type, broken type, oval type and free type. Lee and Kim (2007) classified the type of Korean peninsula heavy rainfall system. Most remarkable characteristic in the development stage was that the strength also increased owing to convective cells merger. That is, both rainfall strength

and rainfall domain increased in the development stage compared with those in the occurrence stage. High EPT concentrated vertically on the ground only was expanded to middle atmosphere, high humidity area at the lower layer moved to middle atmosphere (500 hPa) along the high EPT area, convergence area became stronger on the ground and at the middle atmosphere, and the ascending air current increased along the high EPT area.

In the dissipating stage as low EPT (340 K or less) area penetrates into high EPT that was separated into left and right sides of middle atmosphere (850~500 hPa), northwest wind field appears between south wind field. As low EPT penetrates into high humidity area vertically well developed, there occurs dry area partially in the atmosphere middle layer. There was no more inland convergence but high pressure ridge and the surroundings of the Mt. Jiri changes into low pressure. As no new cells are formed since the mature stage of convective band, the rainfall is weakened or terminated with the band cut in the middle atmosphere.

This study is aimed at analyzing the mesoscale environment and characteristic of airmass type convective bands with heavy rainfall events that occurred in the Honam area from the aspect of convective band life cycle using the case study selected. In the near future further analyses of more examples together with wind field analysis using multi-Doppler radar and mesoscale KLAPS environmental characteristic of convective band with heavy rainfall may expect to be helpful in providing concrete and useful information for short-range forecasters.

Acknowledgements

This study was supported by research fund from Chosun University, 2014.

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