

PAPER • OPEN ACCESS

## Characteristic of anabatic wind in Bandung basin observed by AWS

To cite this article: P Y Kombara *et al* 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **303** 012010

View the [article online](#) for updates and enhancements.



**IOP | ebooks™**

Bringing you innovative digital publishing with leading voices to create your essential collection of books in STEM research.

Start exploring the [collection](#) - download the first chapter of every title for free.

# Characteristic of anabatic wind in Bandung basin observed by AWS

P Y Kombara<sup>1</sup>, I D G A Junnaedhi<sup>1,2</sup>, and E Riawan<sup>1,2</sup>

<sup>1</sup>Weather and Climate Prediction Laboratory, ITB, Indonesia

<sup>2</sup>Research Group of Atmospheric Science, ITB, Indonesia

pyudha@meteo.itb.ac.id

**Abstract.** A field campaign has been done for the wet season in 2015 to identify the pattern of local circulation such as anabatic wind at Bandung basin. In this field campaign, the Automatic Weather Stations (AWS) were installed at seven points from the north until the south region of Bandung basin. The result of this research defines the pattern of anabatic wind in Bandung basin into three categories: the pattern on weak convection, strong convection, and strong convection with rain event. On weak convection condition, after 12.00 LT, the anabatic wind tended to move to the north region of Bandung basin. The wind still moved to the north and south region, on strong convection and strong convection with rain event condition after 12.00 LT. However, after 15.00 LT the wind on strong convection with rain event changed to become northward. On strong convection and strong convection with rain event, the pattern of anabatic wind was influenced by the convective activity in the north and south region of Bandung basin. Whereas on weak convection condition, the pattern of anabatic wind was not influenced by the convective activity.

Keywords : AWS, convection, anabatic wind,

## 1. Introduction

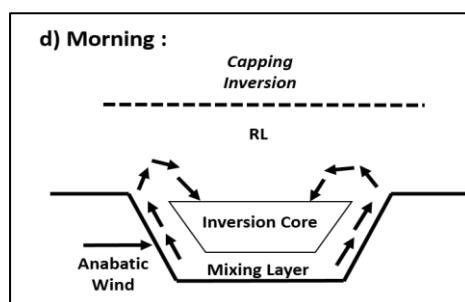
Bandung is one of the areas in West Java, Indonesia which has a complex topographic form. Since the region is surrounded by mountains, it makes Bandung area resembled the shape of a basin, so-called the Bandung basin [1]. The land area that has basin shape will have a local circulation in the form of anabatic and katabatic wind [2]. The existence of local circulation in the Bandung basin has been investigated in the previous studies. Based on the previous research, Bandung basin has a local circulation in the form of anabatic wind that has a semidiurnal pattern [3,4,6]. The prior researches were conducted during the dry season [3] and wet season [4] in 2012 used the SODAR instrument. While in the subsequent research, surface observations by using three AWS placed in the northern part of the Bandung basin has succeeded identify anabatic wind patterns [6]. This research proved the existence of the anabatic wind circulation which was stated in the previous research [3,4].

The previous research still has some weaknesses, which the observation tools used and the number of observation points were still limited so that the existing wind patterns could not be properly described. Therefore, to complement the previous research, the other similar research needs to be carried out on the same basis with the additional observation points so that better observations and wind patterns in the Bandung Basin can be described properly.



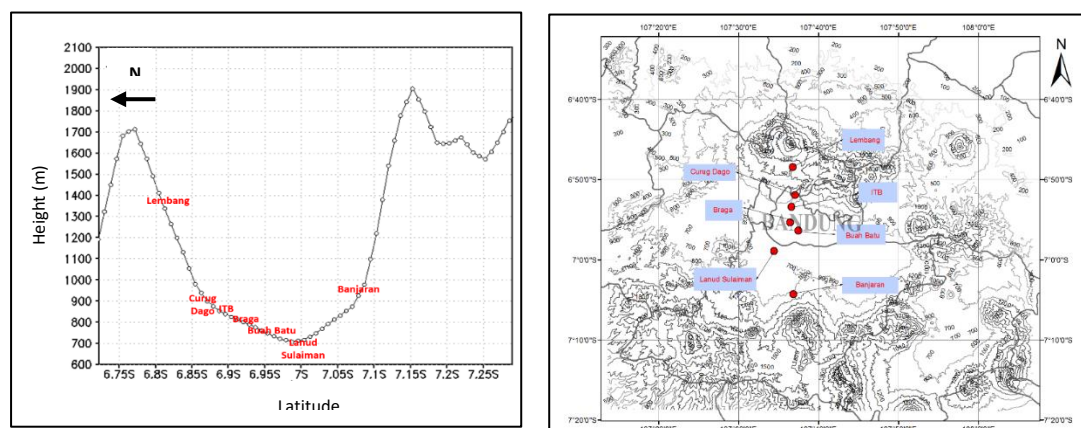
## 2. Data and Method

The method of this study is the surface observation by conducting a campaign using AWS (Automatic Weather Station) which was installed at seven points in the Bandung basin during the wet season to define local wind patterns. This campaign was conducted from mid-December 2014 until the end of January 2015. However, the data used for processing was only six days due to incomplete data on the other days. The dates of the selected days are January 5<sup>th</sup>, 6<sup>th</sup>, 9<sup>th</sup>, 10<sup>th</sup>, 11<sup>th</sup>, and 12<sup>th</sup>, 2015. Observation of local circulation such as anabatic wind circulation requires several weather parameters such as temperature, pressure, humidity, the direction and speed of wind that must be observed simultaneously and follow the instruction from WMO [8]. In addition, observations were made in several places to get more comprehensive weather data. The wind which was defined in this study is the local wind that cuts the valley, so observations were made by referring to the ideal sketch of Stull [5] in the form of a basin as shown in figure 1.



**Figure 1.** Ideal sketch of Stull [5] for local circulation in basin-shaped areas (reproduces from Stull [5])

Cross section and location of the spread point of the observation are shown in figure 2. Observations of this study used three AWS of Davis Vantage Pro, two AWS of Davis Vantage Vue and two MAWS (Meteorology-ITB Automatic Weather Station).



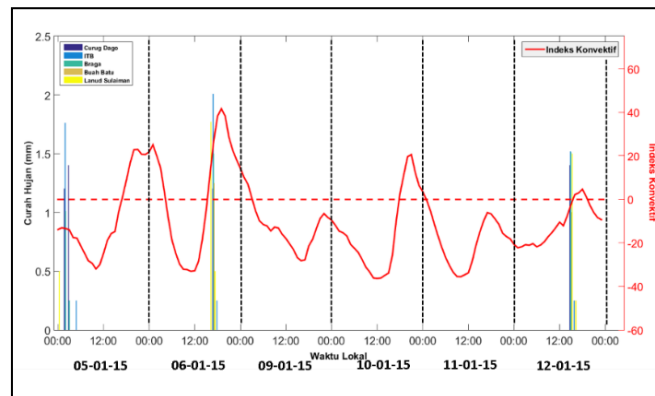
**Figure 2.** Cross section of observation point (left) from north to south and point distribution (right)

The next step is grouping the days to determine the convective conditions occurred during observation by using satellite imagery of MTSAT IR1 data. The convective condition should be determined because during observation the convective conditions were different so that the data must be grouped. Day grouping is done by processing the temperature of black body (Tbb) data on MTSAT IR1 satellite images with the following calculations:

$$CI = 253 - TbbIR1 \quad (Tbb \ IR1 < 253) \quad (1)$$

$$CI = 0 \quad (Tbb \ IR1 > 253) \quad (2)$$

The threshold value of Tbb-IR1 of 253 K [2] is used in this research. After being processed with the above calculation, the results were overlaid with rainfall data to determine which days belong to the strong convective day category accompanied by rain (figure 3). Therefore, the convective conditions can be divided into three categories: weak convective days, strong convective days, and strong convective days accompanied by rain events.



**Figure 3.** Convective index plot of MTSAT IR1 data overlaid with rainfall to determine convective conditions

The results of determining convective conditions are as follows:

Weak Convection (WC): 9<sup>th</sup>, 11<sup>th</sup> January 2015

Strong Convection (SC): 5<sup>th</sup>, 10<sup>th</sup> January 2015

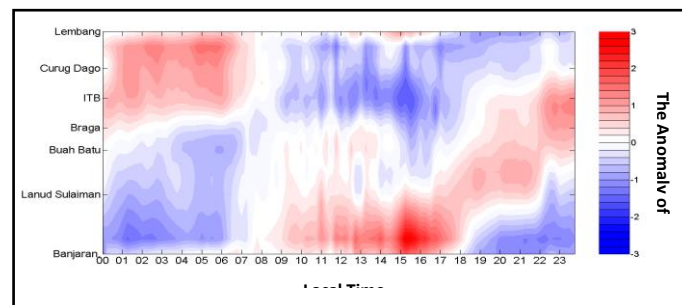
Strong Convection with rain event (SCR): 6<sup>th</sup>, 12<sup>th</sup> January 2015

After being grouped into three convective conditions, the data went into the processing stage. In the first stage, temperature, air pressure and wind were converted to become virtual potential temperature ( $\theta_v$ ), Mean Sea Level Pressure (MSLP) and meridional winds (V Wind). In the second stage, the data of virtual potential temperature ( $\theta_v$ ), Mean Sea Level Pressure (MSLP), and meridional winds (V) were interpolated using linear interpolation method. The interpolation process aims to see diurnal or semi diurnal patterns as seen as an hovmoller image. After being interpolated, the next step was compiling the data and calculating the anomaly. The example of results is shown in figure 4. The existing results were then analyzed spatially and temporally.

### 3. Result

#### 3.1 Weak Convection

At 00.00 to 07.00 LT in Lembang, Lanud Sulaiman, and Banjaran there was a  $\theta_v$  anomaly whose value was negative, while in Curug Dago, ITB, Braga, and Buah Batu, the values were positive. This condition made the air temperature in Lembang and Banjaran was cooler and the air density was large so that the air parcels became heavier. This condition caused the air parcel tended to descend down the slope to the valley. In the valley, there was also a low-pressure center that attracted airflow from Lembang and Banjaran. When looking at the V-wind anomaly (figure 5c) the condition was consistent, the wind from Lembang moved southward while from Banjaran moved northward. In the range between 00.00 - 07.00 LT was called as the katabatic wind regime.



**Figure 4.** An example of linear interpolation results for the  $\theta_v$  parameter

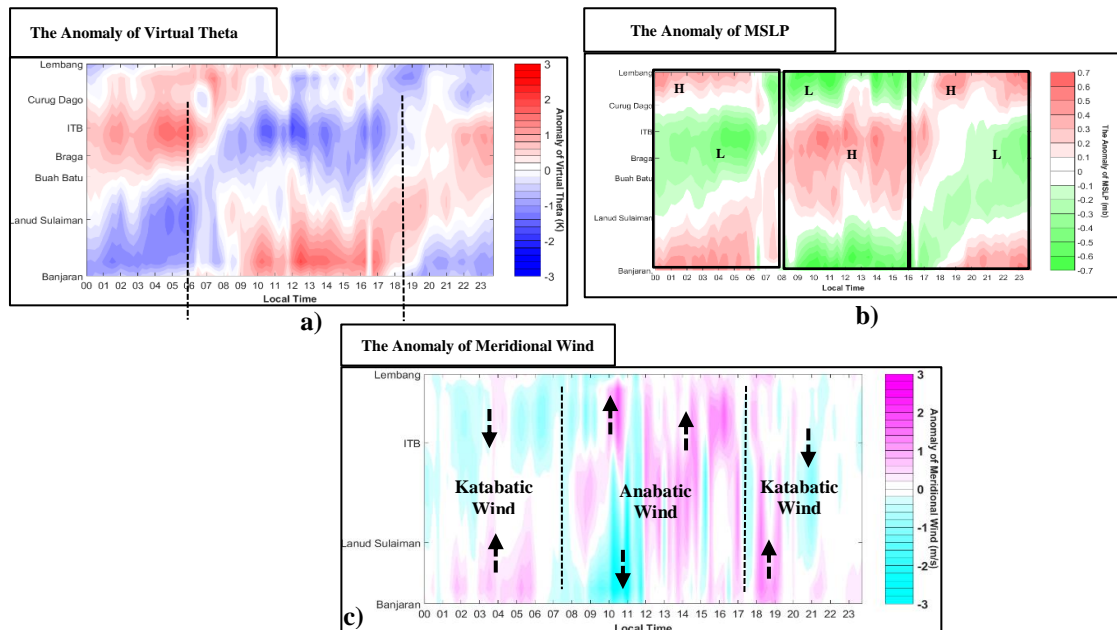
The warming from the sun began to occur at 07.00 LT and it warmed the air around the valley wall. The condition of  $\theta_v$  anomalies in Lembang, Sulaiman Lanud, and Banjaran area showed positive values so that the air density was smaller. Whereas, in Curug Dago, ITB, Braga, and part of Buah Batu area, the anomalies were negative. But for the case of anabatic wind, the difference in air density was not enough to move the air, so the MSLP anomaly condition was also reviewed (figure 5b). There was a low-pressure center in the area of Lembang, Lanud Sulaiman, and Banjaran and on the contrary, the high pressure center existed in parts of Curug Dago, ITB, Braga, and Buah Batu. Since the wind will move from high to lower pressure [9], there should be the wind that moves towards Lembang and Banjaran.

When reviewing the anomaly of V-wind, there was a wind that moved to Banjaran at 07.00-12.00 LT and to Lembang at 09.00-17.00 LT so that the wind conditions were in accordance with the theory and in this span of time it is called as an anabatic wind regime. Based on the theory [5], for anabatic winds there should be wind moving from the center of the valley to the two valley walls in the afternoon at maximum insolation. But for the weak convection conditions, this did not happen. The existence of the wind that moved towards the two valley walls only occurred until 12.00 LT. After that, the wind tended to move to one of the valley walls that was only to the north or Lembang. This was presumably because there was an influence from the position of the sun during the wet season which was in the south of equator.

At 6:00 to 18:00 LT, radiative cooling of the surface began to occur because of the sunset. Radiative cooling in the mountain cooled the surrounding air, causing air to move down the slope towards the valley [5]. Radiative cooling caused air  $\theta_v$  to decrease so that the atmospheric conditions tended to stable again. Therefore, in this span of time, the circulation turned into a katabatic wind regime again.

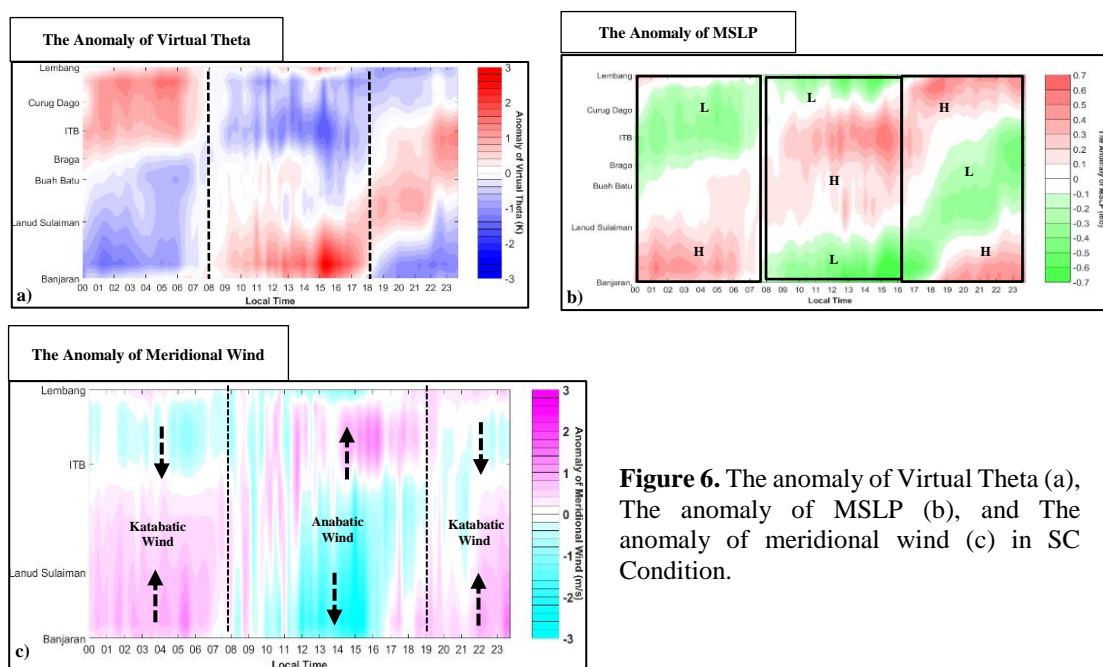
### 3.2 Strong Convection

In the SC condition, katabatic wind regime occurred at 00.00 - 07.00 LT, as in the WC condition. In the morning at 07.00 LT warming from the sun began to occur and warmed the air around the valley wall first. At 10.00 LT, the  $\theta_v$  anomalies in the Banjaran region and part of Lanud Sulaiman showed positive values so that the air density became lighter which caused the air parcels tended to move upwards. However, Curug Dago, ITB, and Braga areas still showed negative  $\theta_v$  anomaly values. The difference in the anomalous value of  $\theta_v$  between the valley floor and the valley wall generated the pressure difference (figure 6b). When referring to the theory [5], during the day there is an anabatic wind moving from the bottom of the valley to the two valley walls. In the SC condition, the anomaly pattern of meridional wind was in accordance with the theory [5]. At 10.00 - 16.00 LT there were positive and negative of V-wind anomalies (figure 6c) at the same time, which showed that there was a wind moving to north and south.



**Figure 5.** The anomaly of Virtual Theta (a), The anomaly of MSLP (b), and The anomaly of meridional wind (c) in WC Condition

This suitability was because in the Bandung basin during the wet season, there was a strong influence of convective activity on both valley walls. However, the anabatic wind regime that moved to the south occurred more strongly than the anabatic wind that moved to the north. This was due to the influence of stronger convective activity in the south. In the north, there was also the influence of convective activity, but the effect was not as strong as in the south. At 5:00 LT heating from the sun weakened and cooling of the surface of the valley walls began to occur. As in WC conditions, at night the katabatic wind regime returned. The negative value of  $\theta_v$  anomaly in both valley walls (Lembang and Banjaran) caused the air density to become heavier so that the air parcel moved down the slope towards the valley floor.

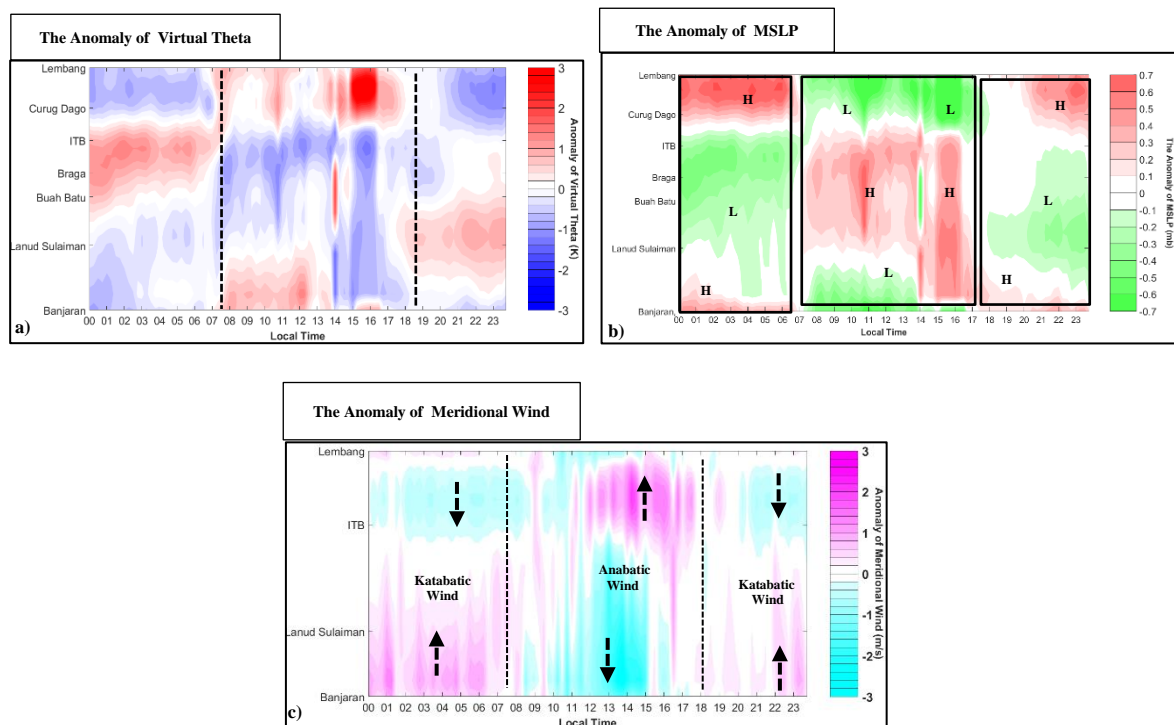


**Figure 6.** The anomaly of Virtual Theta (a), The anomaly of MSLP (b), and The anomaly of meridional wind (c) in SC Condition.



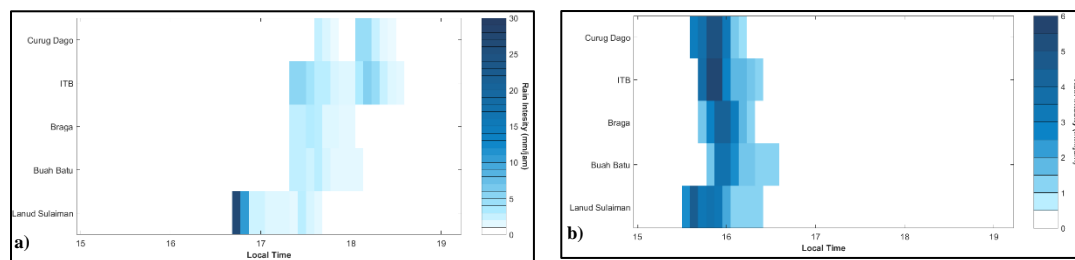
### 3.3 Strong Convection with Rain Event

In the conditions of SCR at the time of 00.00 - 07.00 LT there was a katabatic wind regime. In the morning, there was heating from sunlight that warmed the air near the valley wall. As in the condition of SC, there was also an anabatic wind regime in the SCR condition which was in accordance with the theory [5]. The positive  $\theta_v$  anomaly condition in Lembang and Banjaran areas made the air parcel lighter so that the region became a low-pressure center (figure 7b). Then, there was an airflow that moved from the valley to the north and south of the basin (figure 7c) as in the condition of SC. However, in the SC condition, after 3:00 LT the anabatic wind that moved into Banjaran area suddenly weakened and disappeared. The wind direction was turned towards Lembang. This tendency was similar to the WC condition which occurred after 12.00 LT. The change in wind direction was due to a positive  $\theta_v$  anomaly (figure 7a) which was strong in Lembang region. The positive  $\theta_v$  anomaly caused very low-pressure anomalies (figure 6b) which attracted airflow to Lembang region.



**Figure 7.** The anomaly of Virtual Theta (a), The anomaly of MSLP (b), and The anomaly of meridional wind (c) in SCR Condition.

In addition, at that time in the Bandung basin there were rain events (figure 8a and figure 8b). When the rain stopped, the convective activity has weakened. However, this weakening only occurred in Banjaran region so that anabatic winds that moved into this region has also weakened. The weakening of convective activity in Banjaran caused a change in the pattern of anabatic wind movement in the afternoon of the SCR condition. At night (18.00-00.00 LT) when there was no more solar warming, radiative cooling occurs. Similar to the WC and SC conditions, the katabatic wind regime occurred in the SCR conditions at night. The weight of the air density caused the air mass flew down the slope to the valley which was called katabatic wind (figure 7c).



**Figure 8.** Rain rate on 6 January 2015 (a) and 12 January 2015 (b) in SCR condition.

### 3.4 The Pattern of Local Wind in Bandung Basin on Several Convective Conditions

Cross-valley winds during the day are stronger than at night [7]. Figure 9 shows the scheme of the local wind pattern in each condition and its development with respect to time. The wind speed is shown in the figure as an arrow symbol with different colors. Cross-valley winds in the afternoon showed an anabatic wind. Cross-valley winds during the day or anabatic wind was stronger only in a few conditions. These conditions were WC at 10-12 LT, SC at 13-18 LT, and SCR at 10-15 LT. Furthermore, when comparing the anabatic wind speed between the southern and northern parts, the southern part had a higher speed except for WC conditions at 13.00-18.00 LT and SCR conditions at 16.00-18.00 LT. Stronger anabatic wind speeds in the southern part showed a stronger influence of convective activity in the south when the condition of SC and SCR.

Generally, in the wet season, local wind patterns in the Bandung basin can be divided into three categories, those are Weak Convection (WC), Strong Convection (SC), and Strong Convection with Rain event (SCR) as shown in figure 9. At the WC conditions, the local wind in the Bandung basin begins with katabatic wind at 00.00 - 06.00 LT which blows from Banjaran and Lembang to the center of Bandung Basin or the valley floor. Then in the morning until the evening, an anabatic wind blows coming from the middle of the basin to Lembang and Banjaran. However, these conditions only last until 12.00 LT. Then the anabatic wind tends to blow into Lembang area and there is a weakening of the anabatic wind that blows towards Banjaran. In the evening, the katabatic wind returns from Banjaran and Lembang to the center of the basin.

At the SC condition, at night there is a katabatic wind regime from Banjaran and Lembang to the center of the basin as in WC condition. Furthermore, during the day, it turns into an anabatic wind regime from the center of the basin which blows to Lembang and Banjaran. But unlike the WC condition, the condition of the SC anabatic wind that blows to Lembang and Banjaran lasts until late afternoon. Then in the evening, it changes back to the katabatic wind regime.

As in the WC and SC conditions, the wind pattern in SCR condition begins with a katabatic wind regime and changes in the afternoon to an anabatic wind. Anabatic wind pattern of the SCR condition is similar to the SC condition, except in the afternoon. The anabatic wind blows from the center of the basin to Lembang and Banjaran areas until 15:00 LT. Thereafter, there is an anabatic wind which blows into Banjaran. At that time, anabatic wind tended to move to Lembang. Then in the evening, it changed again to become a katabatic wind regime.

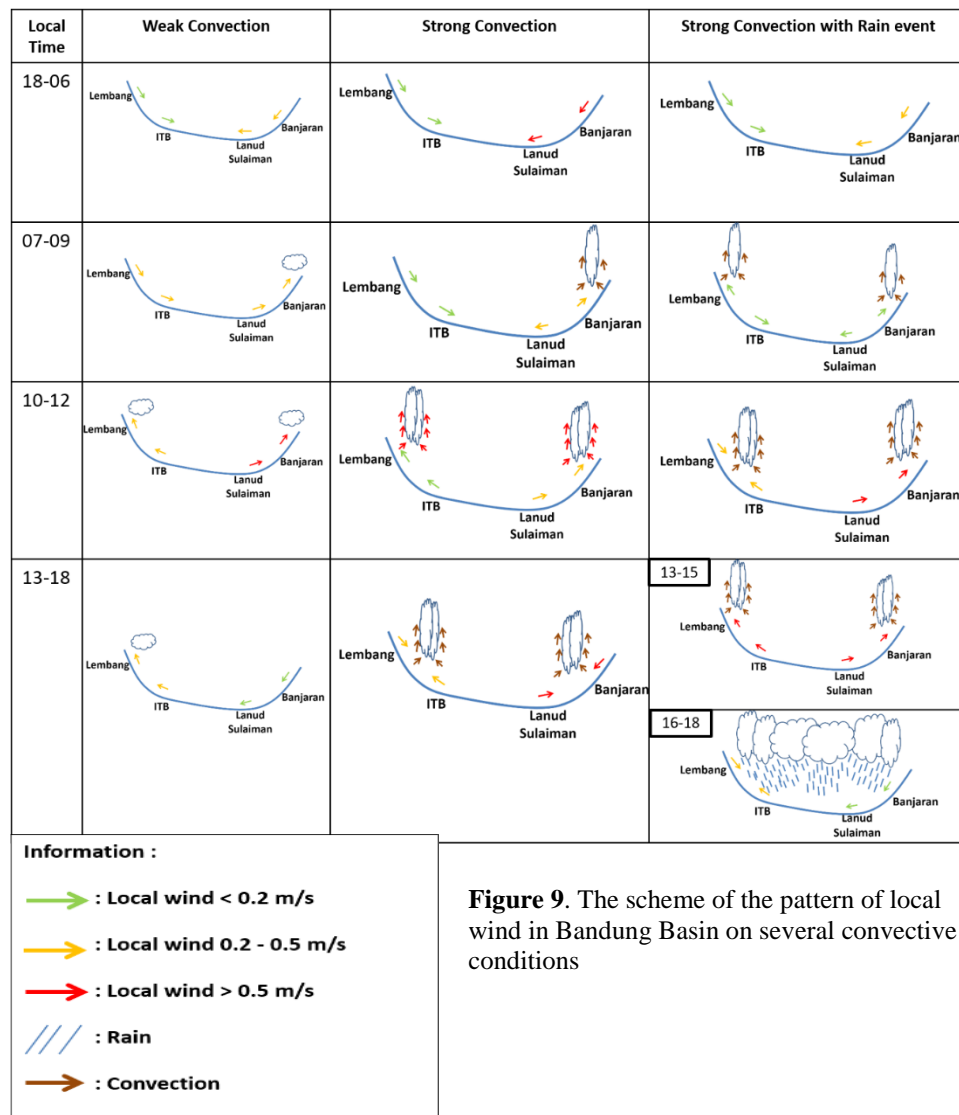
## 4. Conclusion

Based on the analysis of AWS observation data on the seven stations in the wet season, the following conclusions are obtained:

1) Anabatic winds of the Bandung basin during the wet season have three patterns in three conditions (WC, SC, and SCR). At the WC conditions, anabatic wind after 12.00 LT tends to move towards Lembang after previously moving towards Lembang and Banjaran. In the conditions of SC and SCR after 12.00 LT, it still moves towards Lembang and Banjaran, but for SCR at 15.00 LT, its direction changes to Lembang.



2) In WC conditions, the convective activity does not affect anabatic wind patterns. On the contrary, for the conditions of SC and SCR convective activity influences anabatic wind patterns in the Bandung Basin.



**Figure 9.** The scheme of the pattern of local wind in Bandung Basin on several convective conditions

## Acknowledgment

The authors gratefully acknowledge the contribution to WCPL-ITB and crew for valuable assistance while this observation was done.

## References

- [1] Abidin, Hasanuddin Z, Andreas, Heri, Gamal M and Darmawan, D., 2006, Land Subsidence Characteristics of Bandung Basin (Indonesia) between 2000 and 2005 as Estimated from GPS Surveys. (*Munich: Landslide Control and Monitoring Survey*)
- [2] Yang L, Wang Z, Chu Y, Zhao H and Tang M., 2014, *Adv. Atmos. Sci.* **31**: 1386. <https://doi.org/10.1007/s00376-014-3165-9>
- [3] Megatiroika A., 2013, The Analysis of Local Wind at Bandung Basin Based on Data of SODAR Observation and The Result of WRF Model Simulation (*Bandung: Department of Meteorology, ITB*)

- [4] Ramadhan M., 2014, The Analysis of Local Wind of Bandung Basin in Wet Season Based on Data of Sodar Observation, AWS, and MTSAT. (*Bandung: Department of Meteorology, ITB*)
- [5] Stull R B., 1988, An Introduction to Boundary Layer Meteorology (*Boston: Kluwer Academic Publisher*)
- [6] Sugiarto and Aldi Nursepta Nirwana, 2014, The Analysis of Local Wind at North Mountains of Bandung Basin Based on The Data of AWS Observation (*Bandung: Department of Meteorology, ITB*)
- [7] Whiteman C D., 2000, Mountain Meteorology Fundamental and Application (*Oxford: Oxford University Press*)
- [8] WMO, 2008, Guide to Meteorological Instruments and Methods of Observation (*Geneva: World Meteorological Organization*)