RAIN FORECASTING FOR HO CHI MINH CITY USING DOPPLER WEATHER RADAR DWSR-2500C

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ABSTRACT

Rainfall amounts vary randomly over time and space. Rainfall monitoring and forecasting is a difficult task, especially for a short-term period from 30 minutes to 3 hours. Recently Doppler weather radars have been used as one of the new solutions in the short-term forecasting of extreme rain or storm. This research presents some results of forecasting the wind direction, velocity, and rainfall of a typical rainy day, 14 September 2010, based on CAPPI images of a DWSR-2500C radar in the Nha Be district, Ho Chi Minh City (HCMC). The results showed that the Doppler radar, in a scanning radius of 30 km, is very effective in forecasting extreme rainfall for each region and district when reflected radar signals from clouds moving towards the city are detected. This research provides useful information in the forecast of extreme rainfall for flood prevention works in the HCM City.

Keyword: Rain forecast; Doppler weather radar DWSR-2500C; radar signal; CAPPI image

1 INTRODUCTION

HCMC is located between $10^0 10'$N – $10^0 38'$N and $106^0 02'$E – $106^0 54'$E in the south of Vietnam. It is a delta city and the biggest city in Vietnam. HCMC is vulnerable to flooding as a result of land subsidence, high rainfall and climate changes. The land area of HCMC is 2095 km^2, and the average population density was 3719 persons per km^2 in 2012. The current city's population is expected to grow to 9.2 million by 2020 and 10 million by 2025 [1]. The rainy season is from May to November. Rainfall in the rainy season is approximately 80-85% of the annual rainfall. Heavy rains occur in June and September in the range of 250-330 mm/month. The maximum is up to 683 mm. The rainfall intensity is quite high – from 0.8 to 1.5 mm/minute [2]. Average annual rainfall is about 2,000 mm. However, the rainfall is not distributed evenly, but tends to increase in the southwest-northeast axis. Most central districts and northern districts usually have higher rainfall than districts in the south and southwest. Generally, the HCMC's rainfall is highly distributed in a short period of the year and causes water shortages and floods [3]. Therefore, rain forecasts for HCMC are very essential. Using a weather radar in rain forecasts is one of the most advanced techniques with the following advantages: ability to forecast extreme weather phenomena in a short period of time (30 minutes – 3 hours), not achieved by other forecasting methods; highly accurate forecasting for the region near the radar within a radius of 120-240 km. The weather radar has been used to measure rainfall over hilly terrain in north Wales, England [4]. Ground-based radars offer basic and unique advantages, obtaining the continuous three-dimensional space scanning of precipitation events, a short volume-scan period, long range coverage and a high space resolution of measurements [5]. Radar analyses of extreme rainfall were described to clarify the flood-producing rainfall in Charlotte, North Carolina metropolitan area, USA [6]. Radar-rainfall products are crucial for input to runoff and flood prediction models, the validation of satellite remote sensing algorithms, and for the statistical characterization of extreme rainfall frequency [7]. Comparisons of radar and gauge measurements of rainfall were also conducted to examine the accuracy. There is a good agreement between rain gauges and radar rainfall estimates [8-15]. Using weather radars in the assessment of flash flood is very effective [16-19]. This paper shows the overview and results of applying the Doppler weather radar DWSR-2500C in extreme rain forecasts for HCMC.

2 MATERIALS AND METHODS

2.1 Study area

HCMC is composed of districts 1-12, NhaBe (NB), CanGio (CG), BinhThanh (BT), BinhTan (BTA), PhuNhuan (PN), ThuDuc (TD), HocMon (HM), CuChi (CC), BinhChanh (BC), TanPhu (TP), TanBinh (TB), GoVap (GV). The Radar DWSR-2500C is a Doppler weather radar, serving for the southern area and HCMC. Its scan radius is up to 480 km; it operates 24/24 and maximizes its role in weather forecasting, especially for extreme weather. The radar station is located in the NB district with coordinates: 10039'31"N and 106043'42"E. The HCMC map and a radar station photo are shown in Figure 1.

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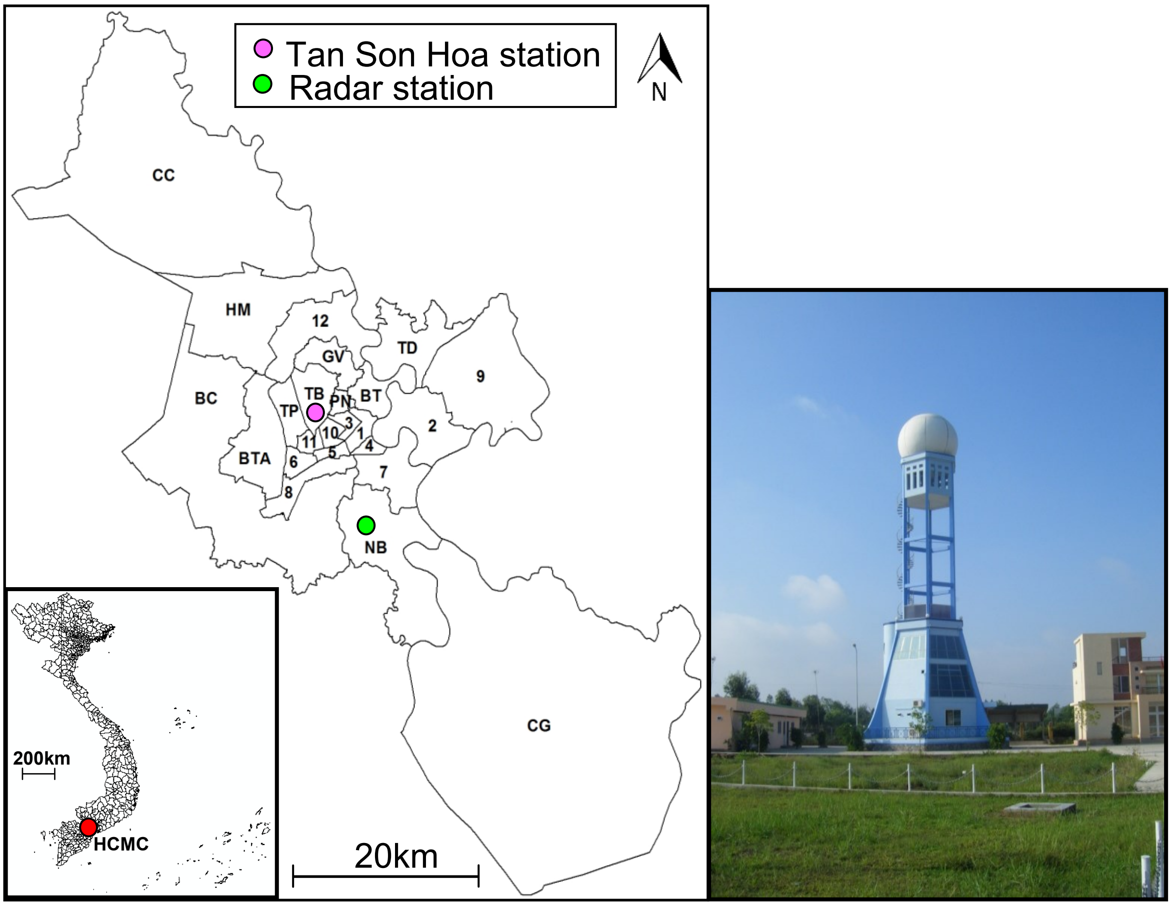

Figure 1: HCMC map and radar station in NB district

2.2 Scanning radii of radar

The Doppler weather radar DWSR-2500C in the NB district uses the EDGE software system to manage and process information throughout its operations. The main function of EDGE consists in controlling the transmitter, receiver, antenna, signal processor of the radar; collecting information; arranging control functions, storage, data mining; creating products; transmitting data. Initially, the scanning radius of 240 km is used to get an overview of weather patterns. This is helpful to detect extreme weather phenomena from far distances in time. Afterwards, the scanning radii of 120 km, 60 km, or 30 km will be used to forecast more accurately.

2.3 Determining moving direction of rain

When detecting the presence of potential clouds through radar images, we need to concern and analyse signals reflected from the clouds to check whether they move into the city or not. These reflected signals are recorded during a certain period of time. It is also possible to use TRACK products of the radar to determine the moving orbit of the potential clouds.

2.4 Velocity of signals reflected from potential clouds

The velocity of the front boundary [20-23] of signals reflected from potential clouds to the interested location A (time from T_{n-1} to T_n) is calculated by the following formula (1):

$$V_n = \frac{L_{n-1} - L_n}{T_n - T_{n-1}} \quad (n=0, 1, 2, 3...) \tag{1}$$

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The time interval of the front boundary of the reflected signals from the location N to the location A is given by (2):

$$\delta T_n = \frac{L_n}{V_n} \tag{2}$$

Rain starting time is the time when the reflected signal zone meets the location A and is expressed by (3):

$$T_{Bdn} = T_n + \delta T_n \tag{3}$$

L_n represents the distance from the n^{th} boundary in front of the reflected signal zone to the location A (km).

2.5 Rainfall analysis from radar images – a typical case of 14 September 2010

Ground rainfall data was measured by a rain gauge in the Tan Son Hoa meteorological station, on 14 September 2010, in HCMC. It began to rain at 16h00 (9h00Z). To observe the overall situation, formation, and the movement of potential clouds which may cause rain in HCMC, we needed to analyse the radar images about 2 hours before the starting time of rain. The radar uses International time (Table 1).

Table 1: Ground rainfall data in Tan Son Hoa station on September 14, 2010

Vietnam time International time	16.00-17.00 9.00-10.00Z	17.00-18.00 10.00-11.00Z	18.00-19.00 11.00-12.00Z	19.00-20.00 12.00-13.00Z	20.00-21.00 13.00-14.00Z	Total daily rainfall (mm)	Maximum rainfall in 60 minutes (mm)	Continuous rainfall (mm)
Rainfall (mm)	38.6	2.7	0.5	2.8	0.3	44.9	39	41.3
Starting - ending time	16.00-18.00		18.30-20.30				16.00-17.00	16.00-18.00
Duration	60	60	30	60	30	240	60	2h00

For comparison with ground rainfall in the Tan Son Hoa station, we used CAPPI image products of the radar.

3 RESULTS

The results of analyses are shown below:

+ At 8:00Z: There is a cloud appearing in 10045’N – 106037’E with a reflected intensity of 39.5 dBz and a rainfall rate of 10.7 mm/h. This is a local convective cloud causing rain in the TB and TP districts (Figs. 2&3).

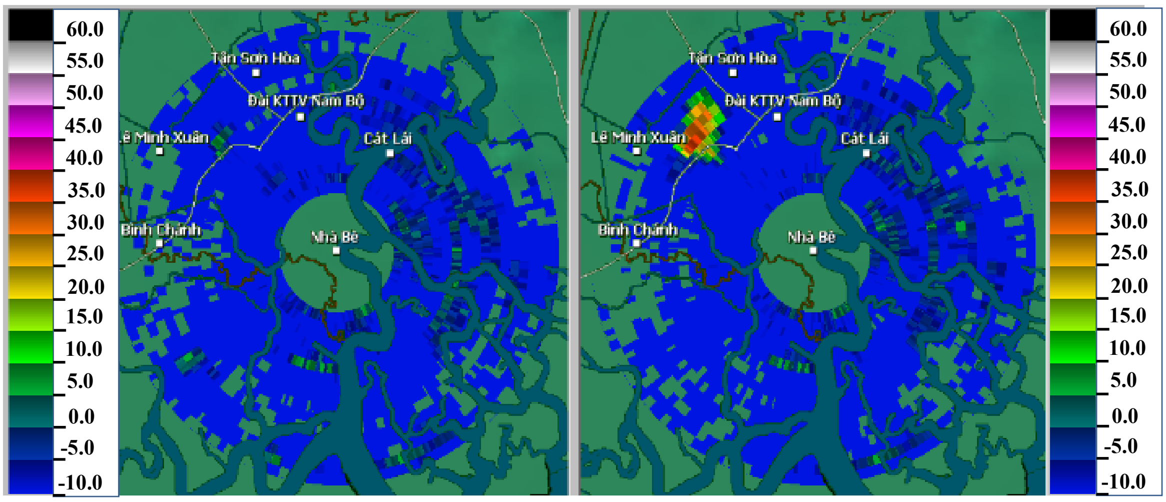

Figure 2: Scanning radius of 30 km at 7:50Z (left) and 8:00Z (right)

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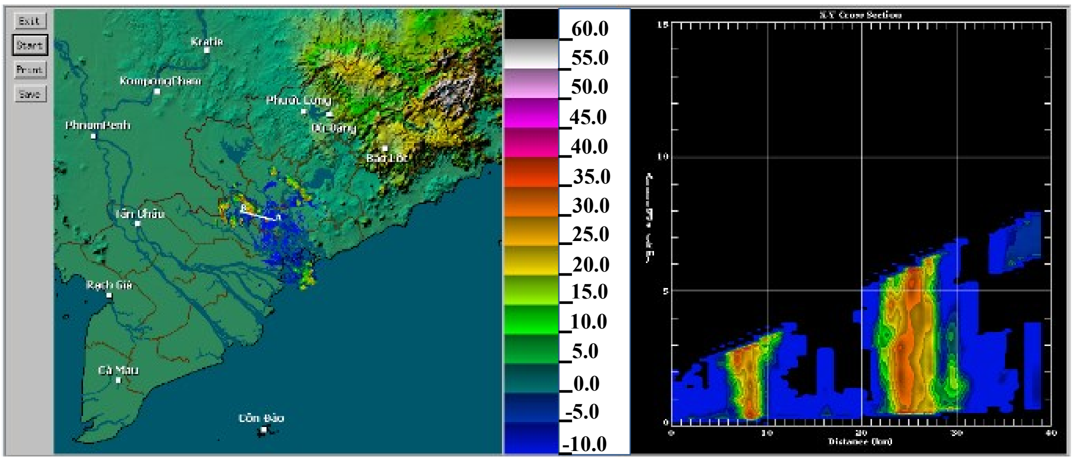

Figure 3: Cross-section of radar signals reflected from cloud at 8:00Z

+ At 8:20Z: The convective cloud continues to develop and move towards the east of the city. The reflected intensity reaches 42 dBz with a rainfall rate of 15.4 m/h. Rain appears in the TB, TP, 3, and 10 districts (Figs. 4&5).

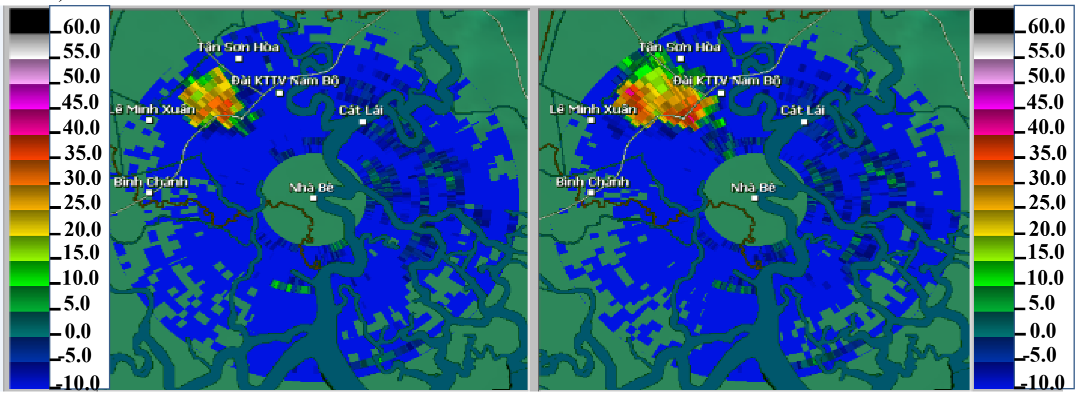

Figure 4: Scanning radius of 30 km at 8:10Z (left) and 8:20Z (right)

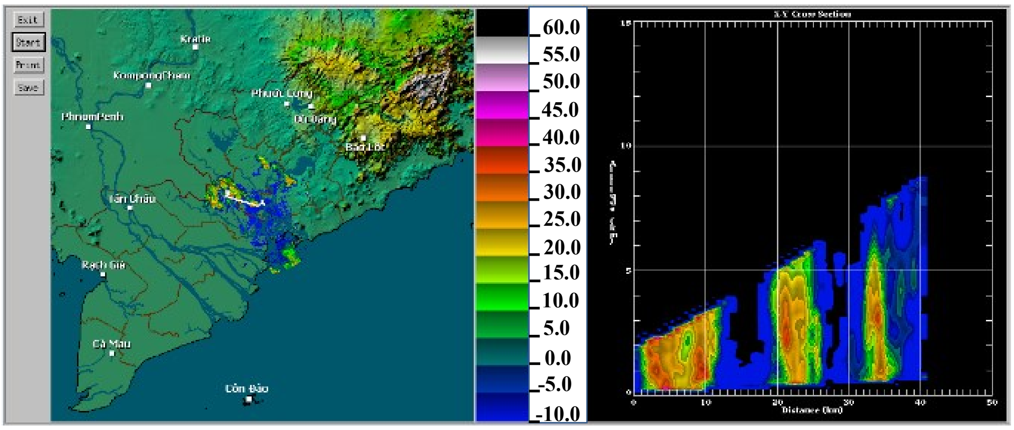

Figure 5: Cross-section of radar signals reflected from cloud at 8:20Z

+ At 8:30Z: The convective cloud in the city moves towards the southeast and causes rain for nearly the whole city. The maximum rainfall rate of 2.7 mm/h is obtained in the districts 1, 2, 4, 7, and the TP district with an intensity of 30 dBz. At this time, a new reflected signal with an intensity of 40 dBz, a rainfall rate of 11.5 mm/h appears far away and moves towards the city (Figs. 6&7).

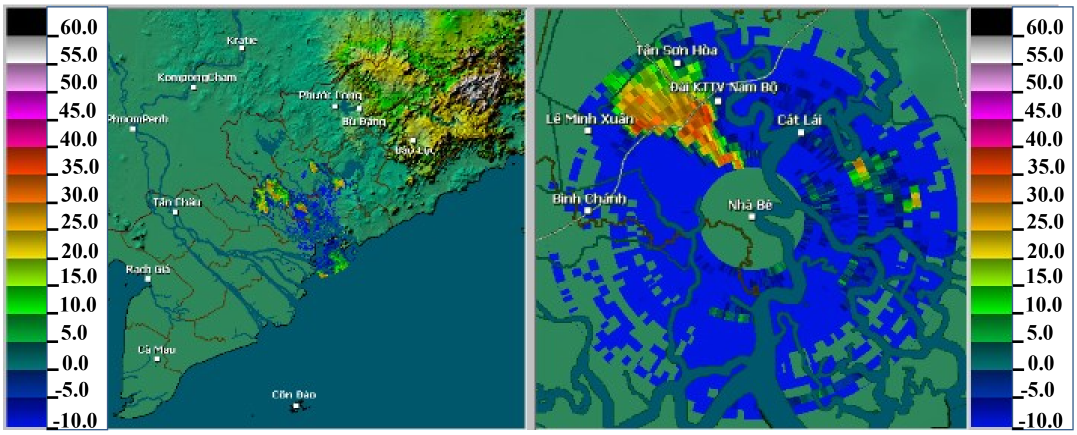

Figure 6: Scanning radius of 240 km (left) and 30 km (right) at 8:20Z

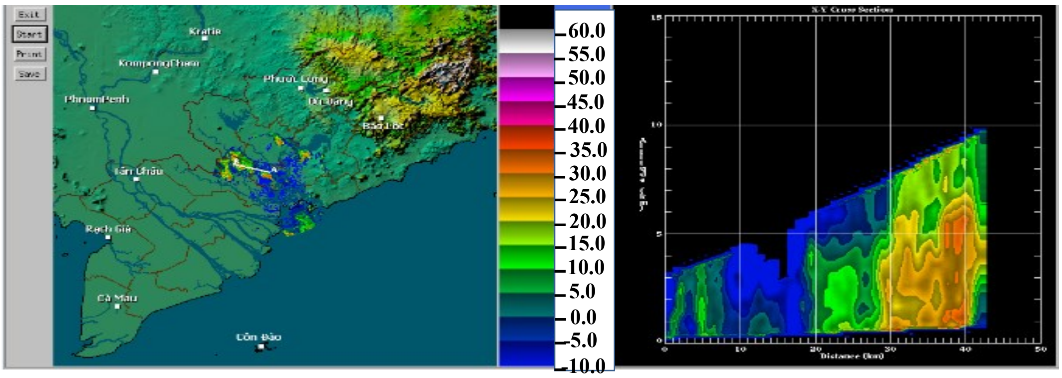

Figure 7: Cross-section of radar signals reflected from cloud at 8:30Z

+ At 8:40Z: The convective cloud continues to cause heavy rain in the city centre and keeps moving towards the southeast. The maximum intensity reaches 41 dBz and rainfall is 13.3 mm/h in the districts 1, 3, 4, 7, 10, TP and the NB district. A new reflected signal continues to develop strongly with the maximum intensity of 37.5 dBz, a rainfall rate of 8.0 mm/h and is 30 km from the city (Figs. 8&9).

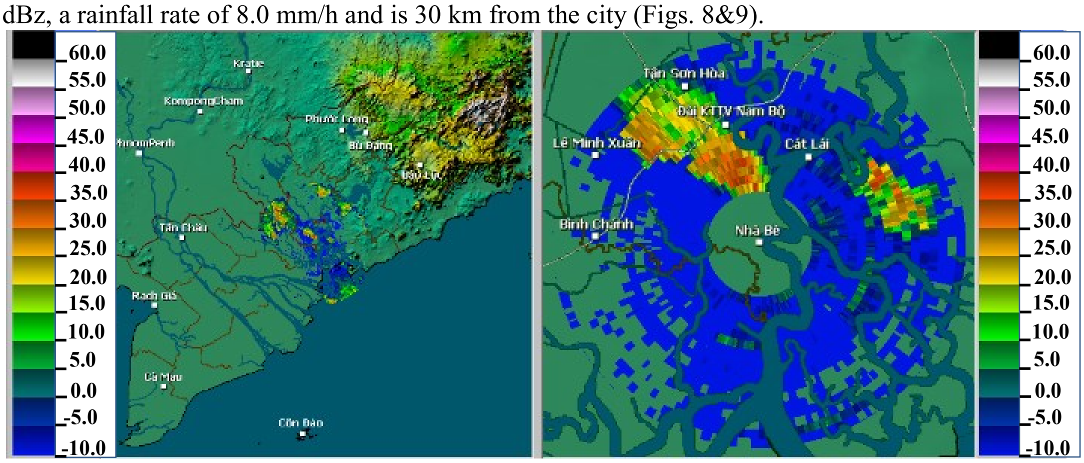

Figure 8: Scanning radius of 240 km (left) and 30 km (right) at 8:40Z

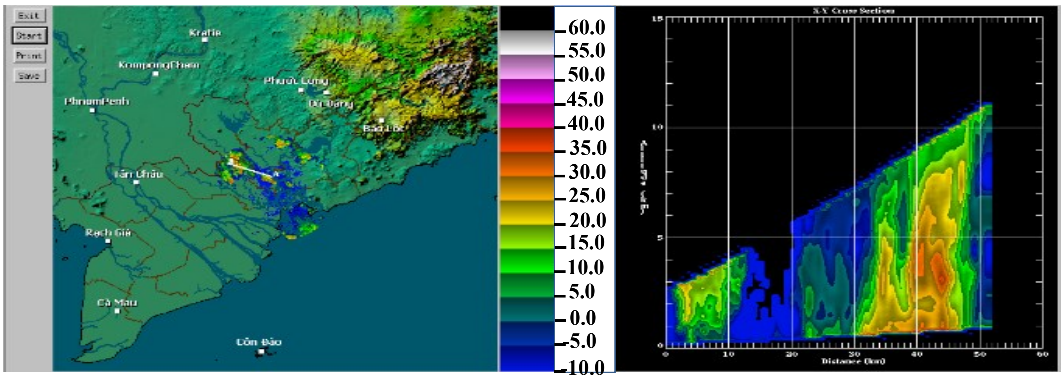

Figure 9: Cross-section of radar signals reflected from cloud at 8:40Z

+ At 8:50Z: The rain produced by the convective cloud decreases in the city centre but becomes heavier in the southeast – the districts 4 & 7, and maximum in the NB district with an intensity of 42 dBz and a rainfall rate of 15.4 mm/h. While the new reflected signal is 27 km from the city, the intensity decreases to 36.5 dBz with a rainfall rate of 7.0 mm/h (Fig. 10).

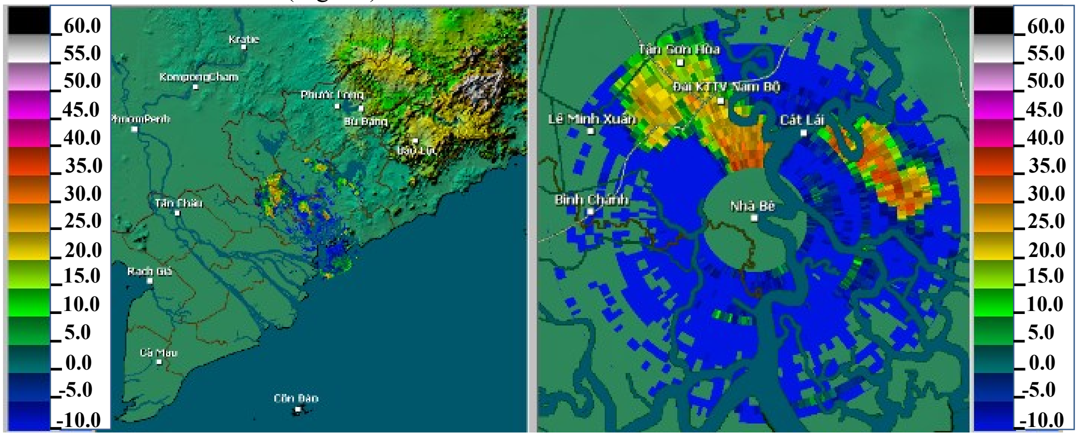

Figure 10: Scanning radius of 240 km (left) and 30 km (right) at 8:50Z

+At 9:00Z: The convective cloud continues to cause heavy rain in the southeast of the city, especially in the NB district. The intensity is 40 dBz with a rainfall rate of 11.5 mm/h. A new reflected signal continues to develop more strongly (Figs. 11&12).

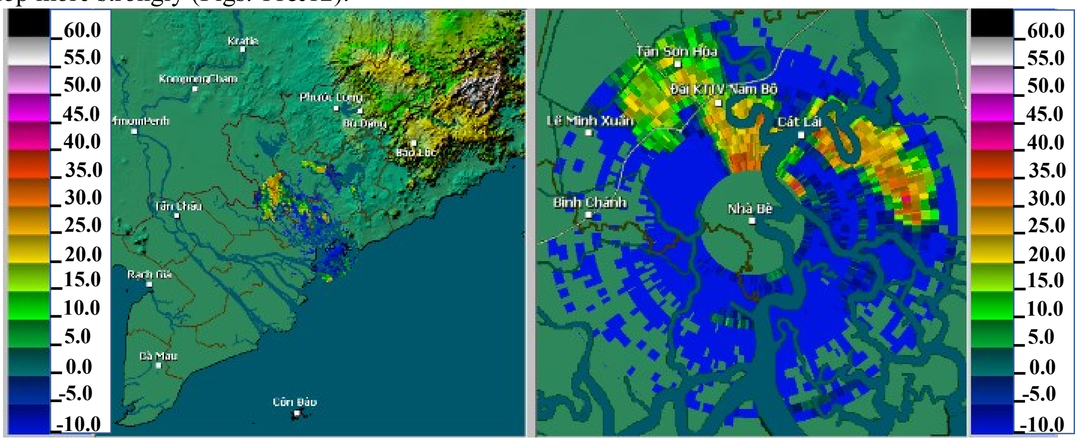

Figure 11: Scanning radius of 240 km (left) and 30 km (right) at 9:00Z

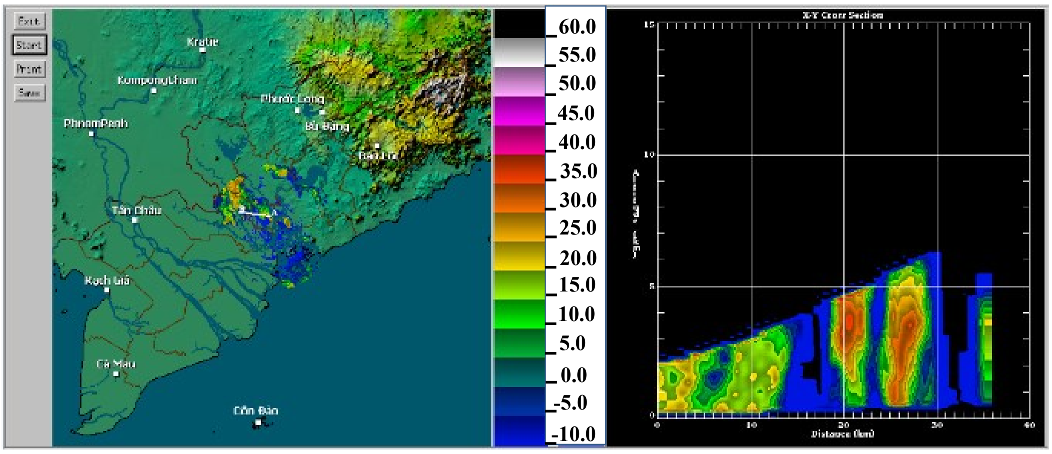

Figure 12: Cross-section of radar signals reflected from cloud at 9:00Z

+ At 9:10Z : In the southeast of the city – the districts 2, 4, 7 and mainly the NB district are still having heavy rain. The intensity reaches 35.5 dBz with a rainfall rate of 6.0 mm/h. The new reflected signal is still stronger and 18 km from the city with a velocity of 1 km/10 min (Figs. 13&14).

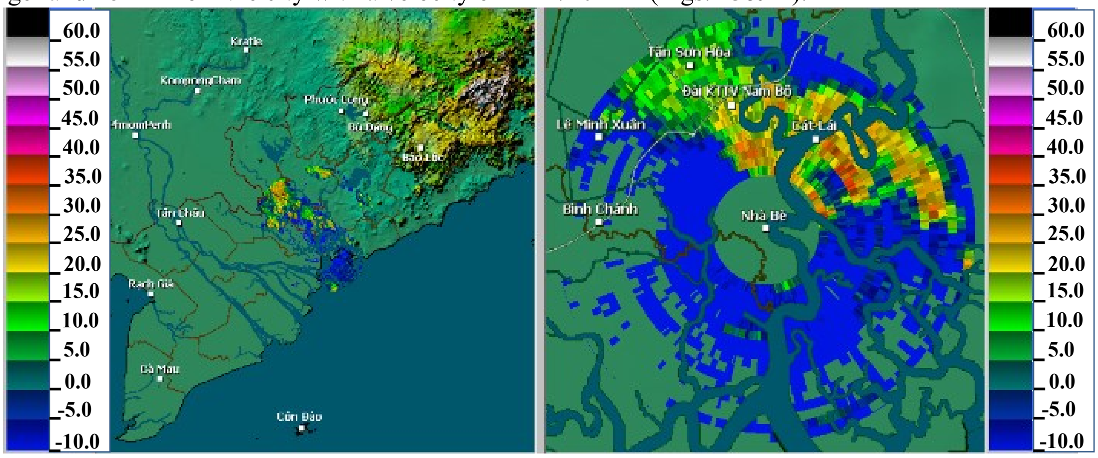

Figure 13: Scanning radius of 240 km (left) and 30 km (right) at 9:10Z

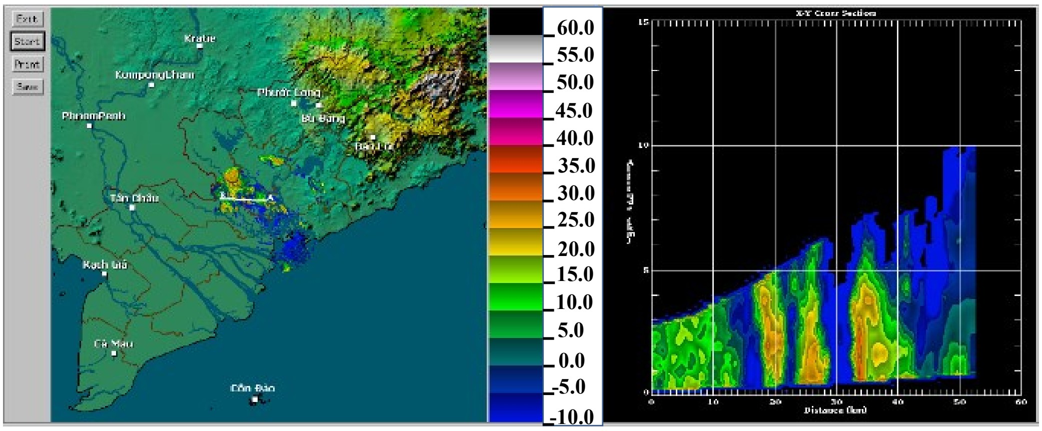

Figure 14: Cross-section of radar signals reflected from cloud at 9:10Z

+ At 9:20Z: The reflected signal is 15 km from the city. The intensity reaches 37 dBz with a rainfall rate of 7.5 mm/h (Fig. 15).

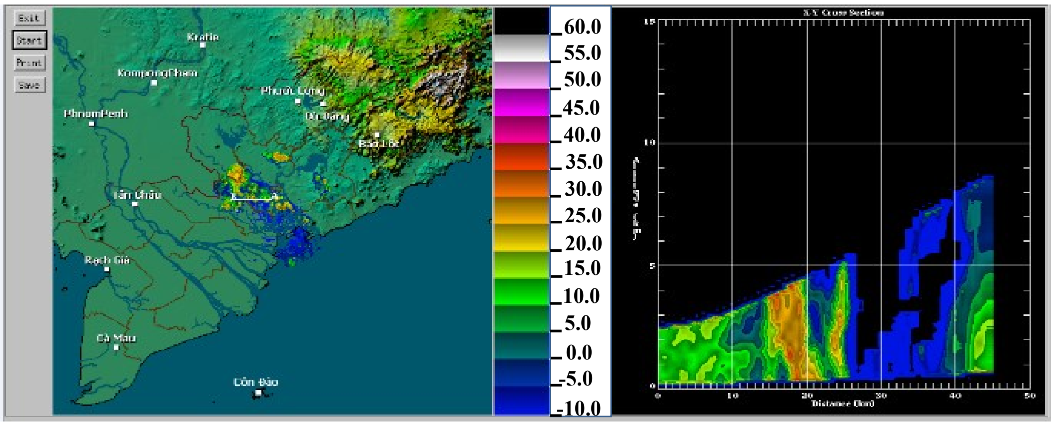

Figure 15: Cross-section of radar signals reflected from cloud at 9:20Z

+ At 9:30 Z: The reflected signal is 12.5 km from the city. The intensity reaches 40 dBz with a rainfall rate of 11.5 mm/h (Fig. 16).

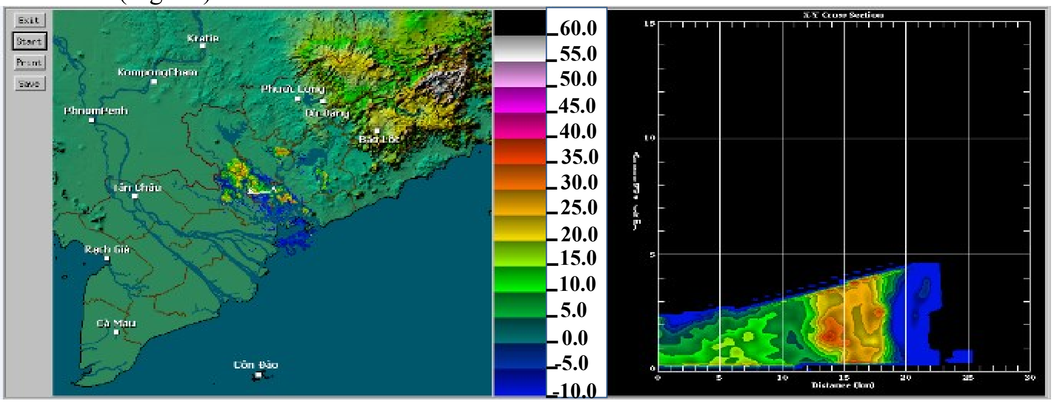

Figure 16: Cross-section of radar signals reflected from cloud at 9:30Z

+At 9:40Z: The reflected signal is 11 km from the city. The intensity decreases to 39 dBz with a rainfall rate of 10.0 mm/h (Fig. 17).

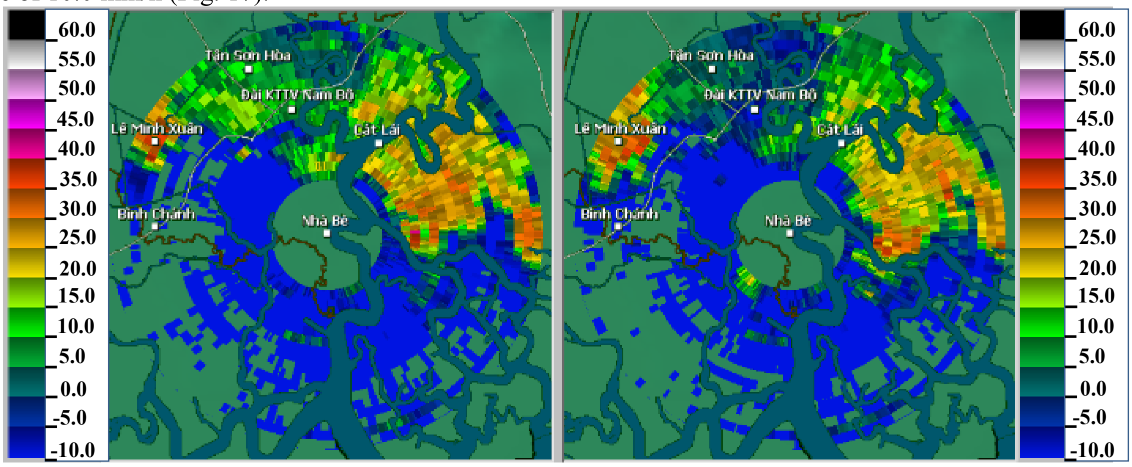

Figure 17: Reflected radar signals in city at 9h30Z (left) and 9h40Z (right)

+ At 9:50Z: The intensity of the reflected signal increases to 43 dBz with a rainfall rate of 17.8 mm/h. It causes rain in the vicinities of the city centre like the BC district (located northwest of the city) (Fig. 18).

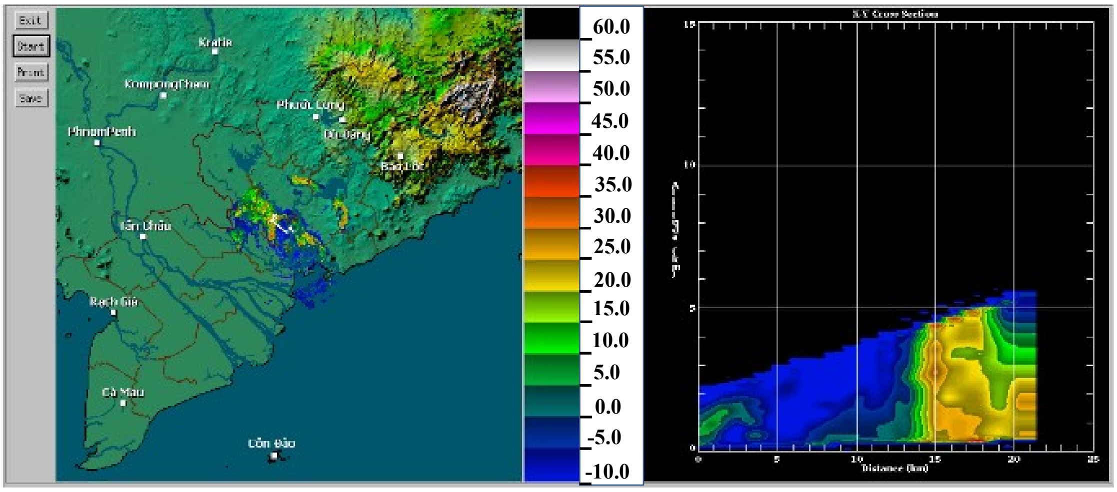

Figure 18: Cross-section of radar signals reflected from cloud at 9:50Z

+ At 10:00Z: The reflected signal zone still causes rain in the northwest of the city. There are some places with an intensity of 44 dBz and a rainfall rate of 20.5 mm/h. The reflected signal zone has a tendency to move towards the south and causes rain in the western ridge areas; however, it does not move to the city centre (Fig. 19).

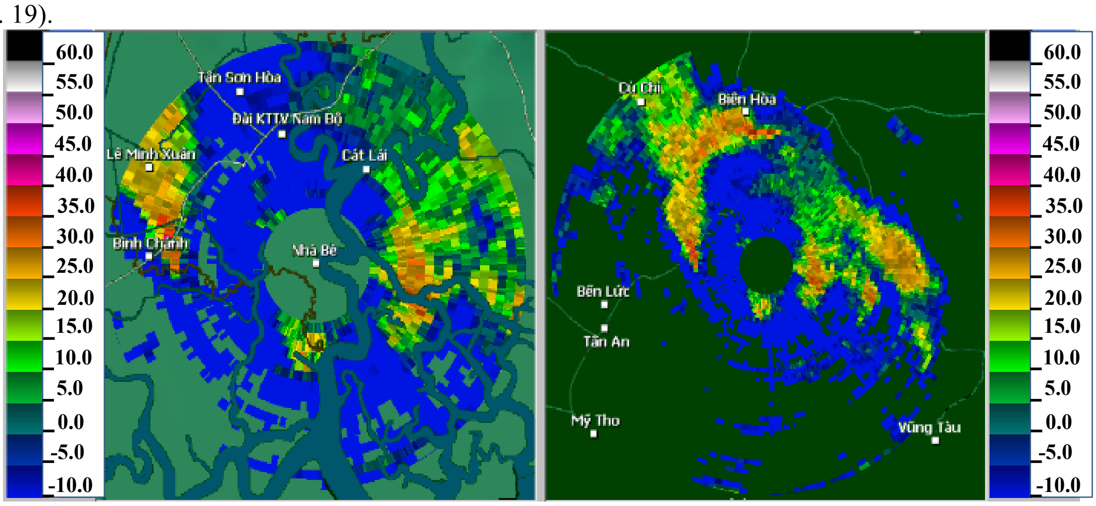

Figure 19: Scanning radius of 30 km (left) and 60 km (right) at 10:00Z

Obviously, when comparing the rain event in Tan Son Hoa station (starting time 9:00Z) to the potential cloud moving towards the city detected by the radar at 8:00Z, we see that radar is able to forecast rain in a short time effectively.

4 CONCLUSION

Using the Doppler weather radar DWSR-2500C to monitor the change of rain and extreme weather patterns over wide areas gives fairly accurate results. Depending on the region and case, analyses require appropriate scanning radii. For rain forecasting in HCMC, the weather radar in the NB district initially uses the scanning radius of 240 km to observe weather patterns. Afterwards, the scanning radii of 120 km, 60 km, or 30 km will be used to forecast more accurately. It is realized that when the signal reflected from clouds moves closer to the city, the scanning radius of 30 km is very effective in a short period of time (30 minutes to 3 hours). This research provides useful information for flood prevention works in HCMC.

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