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Landspout and Hail Detection Utilizing Radar Products

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Abstract

The occurrence of hail and landspout are needed to study by forecasters for issuing the severe weather warnings to publics and agencies related to disaster mitigation. The radar products that consisted of reflectivity and velocity products are mainly used for the severe weather analysis. The indicator of cyclonic, anti-cyclonic, divergence or convergence using velocity products can provide the signature of adverse weather phenomenon. Meanwhile, the vertical crosssection of reflectivity products beneficial for two-dimensional views of radar echoes. In fact, the height of cloud and details structure of cloud with its development of storms can be determined using this technique. In this findings, the landspout is hard to detect because its presence typically happen before the precipitation occurs. The short-lived and weak characteristics of landspout is not possible to detect by Doppler radar data since the interval time of velocity products is every 30 minutes. Hence, more studies are needed to find the characteristics of landspout in Malaysia. In the meantime, study by Japan Meteorology Agency (JMA) using Numerical Weather Prediction (NWP) Potential Indices Model discovered that the landspout can be predicted one day before the occurrence using this model. Therefore, it is recommended to study about this model for delivering the landspout warnings issuance. Subsequently, the hail phenomenon can be detected by utilizing the vertical cross-section of reflectivity products which 55 dBZ and above can produce hails at the storm areas with the condition of time period should be greater than 30 minutes. In conjunction with top of cloud that greater than 15 km and point of maximum reflectivity higher than freezing level values (0◦C) from radiosonde data can help forecasters to determine the hail occurrence. As a result, the issuance of hail warnings can be issued by analysing the radar products related to velocity and reflectivity products. Though, issuance of landspout warnings have to be studied further on another radar products or the velocity products should be improved to every 10 minutes. On the other hand, radar as observation tool consisted of many products that can be examined for further research in disseminating of adverse weather warnings. The forecasters have to bear in mind that the radar products should be investigated in term of characteristics, features and significant indicator of severe weather events in association with satellite, tephigram and observation data for the accurate of dissemination of warnings.

Acknowledgement

I would like to express the deepest appreciation to experts of Japan Meteorological Agency (JMA) Mr. Masahisa NAKAZATO, Mr. Hiroshi YAMAUCHI, and Mr. Takanori SAKANASHI for continuous co-operation from Weather Radar Workshop, 2 – 6 November 2015 in Malaysian Meteorological Department (MMD), Petaling Jaya.

1. Introduction

Radar is an operational tool that can provide observation of severe weather detection and tracking in term of temporal and spatial resolutions that enable weather warning issuance to publics and other agencies related to disaster mitigation. In Malaysia, radars capabilities can provide a two-dimensional view every 10 minutes at temporal resolution and 1 km or less for the spatial resolution which the coverage for Doppler S-band and C-band Radar is 300 km in range. In line with the high technology in radar, Terminal Doppler Weather Radar (TDWR) is installed near the airport with the better temporal resolution (every 1 minute) to highlight the severe weather warning especially for the aviation purpose such as Subang and KLIA Radar Station. The coverage for the TDWR purpose is less than 300km, but the sequence and scanning elevation angles give some advantage for the severe weather warning issuance since the forecasters can analysis more on the weather pattern. In addition, dual polarization radars which are highly recommended to differentiate between non-meteorological or meteorological targets, now widely been used all over the world. The products such as differential reflectivity (ZDR) and specific differential phase (KDP) respectively can be used to distinguish hail, rain or non-rain echoes.

Indeed, the radar observation is able to detect severe storm and tornado warnings, hurricane observations, flood warnings and wind shear warnings that resulting in the reduction of life and properties losses (E.Rinehart, 2004). Weather radar detects various severe weather events which can be defined as heavy rains, hail, strong winds including tornadoes. The characteristics for each events should be studied by utilizing radar products. Many studies were already discussed to identify adverse weather events by (Joe, et al., 2012) for delivering watches and warnings to the society. This study will be emphasized on landspout and hail events to provide the details features for forecasters in detecting these severe weather events in Malaysia. Landspout can be categorized as small tornadoes that not bring more significant such as real tornadoes happened in other country since the real tornadoes contribute to the significant signature on the radar displays such as hook echoes, area of enhanced reflectivity and bounded weak echo region. Hails also can be identified by making cross-section of reflectivity products.

From the view of (D.Crum & L.Alberty, 1993), reflectivity cross-section is essential to analysis a storm’s structure and identify the height of maximum reflectivity, weak echo region and storm tilt. The vertical cross-section of reflectivity product will be displayed by selecting the beginning and ending points of radar echoes which was derived from the complete volume scan. In addition, the velocity products presented the presence and strength of convergence and divergence patterns, which are vital in the stages of storm’s life cycle and examine the depth and strength of mesocyclones. Due to lack of knowledge in analysing of radar products, the forecasters may provide insufficient weather warning alerts. Furthermore, it probably contribute some misperception to the forecasters. As a result, the analysis of detection of hails and landspout events will be studied by choosing the respective period and utilizing the radar products for providing information to the forecasters the importance of analysing radar echoes especially in the adverse weather phenomenon.

2. Data and Methodology

For the analysis of severe weather occurrence in Malaysia, S-band Doppler weather radar namely Alor Star, Butterworth, Subang, KLIA and Kuantan stations are selected from the chosen events as illustrated in Table 1. Table below shows the occurrence date and location of severe weather event which focused on the landspout and hail. Figure 1 presents the position of events together with location of radar.

Table 1: The occurrence date and location of selected events

Date	Location	Event	Location Point
14 October 2014	Pendang, Kedah	Landspout	5.983°, 100.417°
21 October 2014	Pandamaran, Selangor	Landspout	3.0106882°, 101.42114°
31 October 2014	Kota Setar, Kedah	Landspout	6.115894°, 100.36478°
12 November 2014	Kota Sarang Semut, Kedah	Landspout	5.9833°, 100.4°
2 March 2014	Semenyih, Selangor	Hail	2.9513°, 101.8523°
7 August 2015	Bandar Jengka, Pahang	Hail	3.74° , 102.565°
3 June 2016	Bukit Jalil, Selangor	Hail	3.0587° ,101.6917°

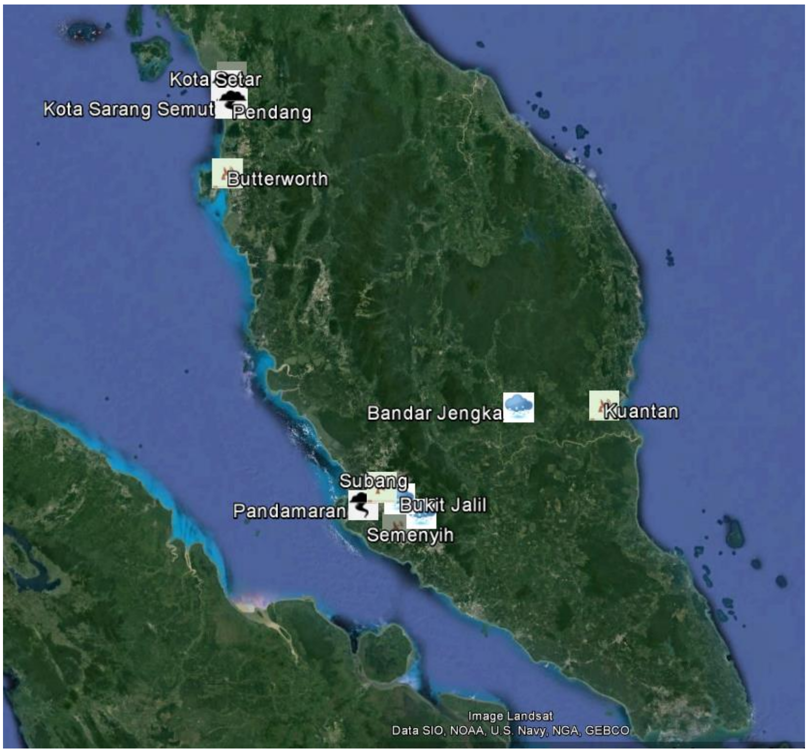


Figure 1: The location of landspout and hail events with radar station used in the analysis

A selection of radar products such as base reflectivity, base velocity and cross-section of rain echoes are analysed to investigate the characteristics of representative echoes. Generally, base reflectivity displays the amount of power after it has reflected off targets in the atmosphere. The usual range as shown in Table 2 (NWS NEXRAD) indicate the intensity for each radar reflectivity (dBZ) for different Z-R relationship, Marshall Palmer ($Z = 200R^{1.6}$) and

Rosenfeld (Z= $250R^{1.2}$). In the meantime, base velocity can determine the signature of severe weather that indicate probably wind shear or mesoscale event such illustrated in Figure 2.

Table 2: Radar reflectivity, rainrate and its intensity for different Z-R relationship

dBZ (Radar reflectivity)	Marshall Palmer (mm/h)	Rosenfeld (mm/h)	Intensity
5	0.07	0.03	Hardly noticeable
10	0.15	0.07	Light mist
15	0.3	0.18	Mist
20	0.6	0.47	Very light
25	1.3	1.22	Light
30	2.7	3.18	Light to moderate
35	5.6	8.29	Moderate rain
40	11.53	21.63	Moderate rain
45	23.7	56.46	Moderate to heavy
50	48.6	147.36	Heavy
55	100	384.64	Very heavy/small hail
60	205	1004.00	Extreme/moderate hail
65	421	2620.50	Extreme/large hail

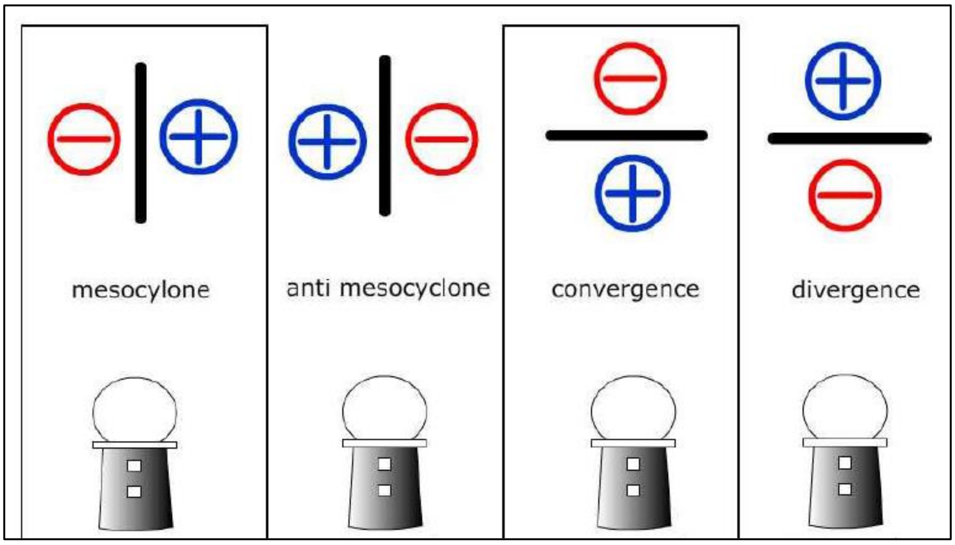


Figure 2: The signatures from point of radar based on velocity products

Hydrometer / scattering target discrimination

*1 : Doviak and Zrnic 1993
*2 : Anderson et al 2011
*3 : Ryzkov et al 2005

Target	Z (dBZ)	ρhv	Zdr (dB)
Rain	small~large 25~60*1	large 0.97<*1	small~large 0.4~4*1
Hail	large 50<*2	middle 0.95<*1	middle~large 3~8*2

Figure 3: The table of hydrometeor target discrimination between hail and rain (Courtesy:JMA)

Figure 3 shows the hydrometeor target discrimination between hail and rain echoes. (*1: Doviak and Zrnic 1993, *2: Anderson et al 2011, *3: Ryzkov et al 2005). Since radar dual polarization products are beneficial to detect hail and non-meteorological echoes as showed in Figure 4, the products such as Differential Reflectivity (ZDR) and Specific Differential Phase (KDP) as listed in Table 3 are used for the analysis.

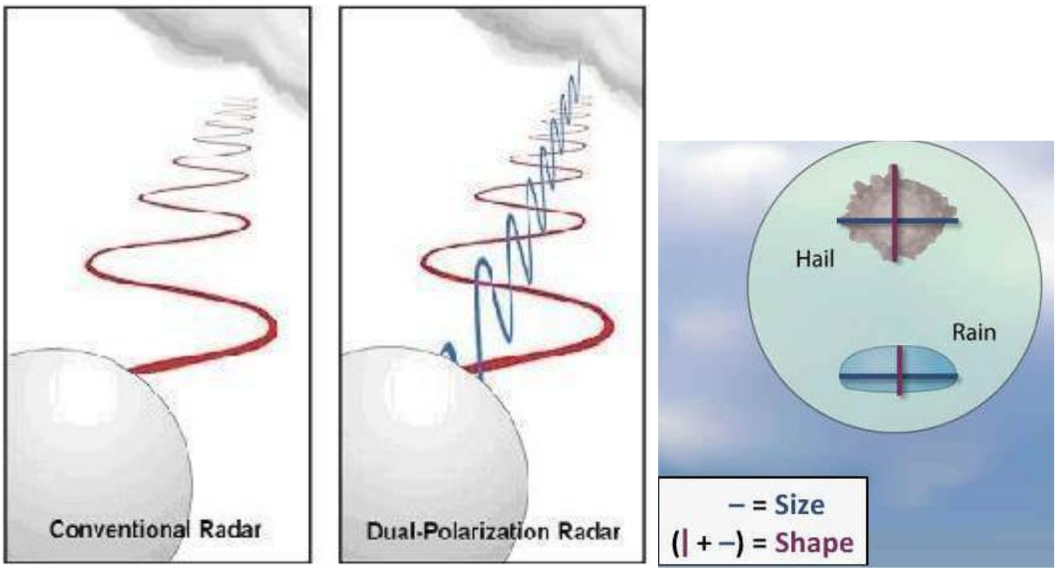


Figure 4: The polarimetric radar can transmit and receive both vertical and horizontal polarizations to determine size, shape and variety of targets. (Courtesy: NOAA)

Table 3: Product of Dual Polarization

• Differential reflectivity Z_{DR}	➢ Depends on the particle size, shape, orientation and density ➢ Measure of the median raindrop diameter ➢ Efficient for discrimination between rain and snow ➢ ZDR > 0 indicate horizontally oriented such as rain or melting hail
• Specific differential phase K_{DP}	➢ The range derivative of the differential phase shift between the horizontal and vertical pulse phases ➢ Basically KDP range between -2 to 7 deg/km for rain

As Malaysia has only two dual-polarization radar station namely KLIA and Subang radar station, the detection of hails also can be done using the single polarization radar which was studied by (Holleman, 2001) such as CAPPI-Method, Maximum Reflectivity-Method, NEXRAD Hail Algorithm and Vertical Integrated Liquid (VIL). In this study, we will emphasize on the CAPPI-Method and Maximum Reflectivity Method for this purpose. Meanwhile, from the point view of (Smith, 1996) landspout existed by the stretched and tilted upward of developing thunderstorm updraft not from the mesocyclones and supercells. They were usually observed by association with lines of cumulus congetus or towering cumulus clouds, often before precipitation is visible on radar. Landspout is indicated by the rotational signatures and the movement of low-level convergence boundaries. Hence, this study is needed to investigate the features of landspout detection by radar before and after the events occurred.

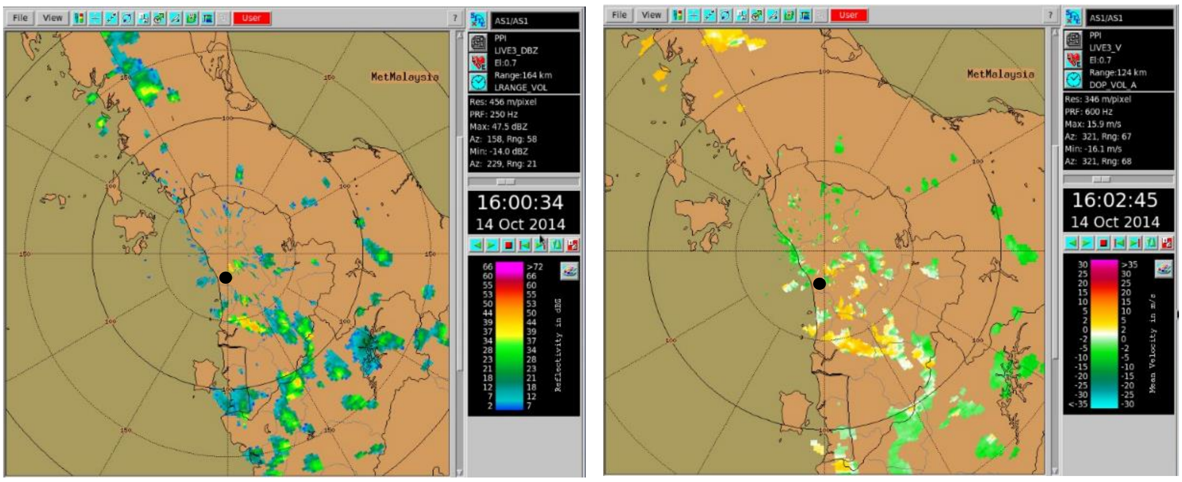
3. Results and Discussion

Seven events related to landspout and hail phenomenon are chosen for this study as listed in Table 1 will be presented and discussed.

3.1 Landspout Events

a) 14th October 2014, Pendang Kedah (Time:1630pm)

Figure 5: The image of landspout at location in Pendang, Kedah (Courtesy: The Star)



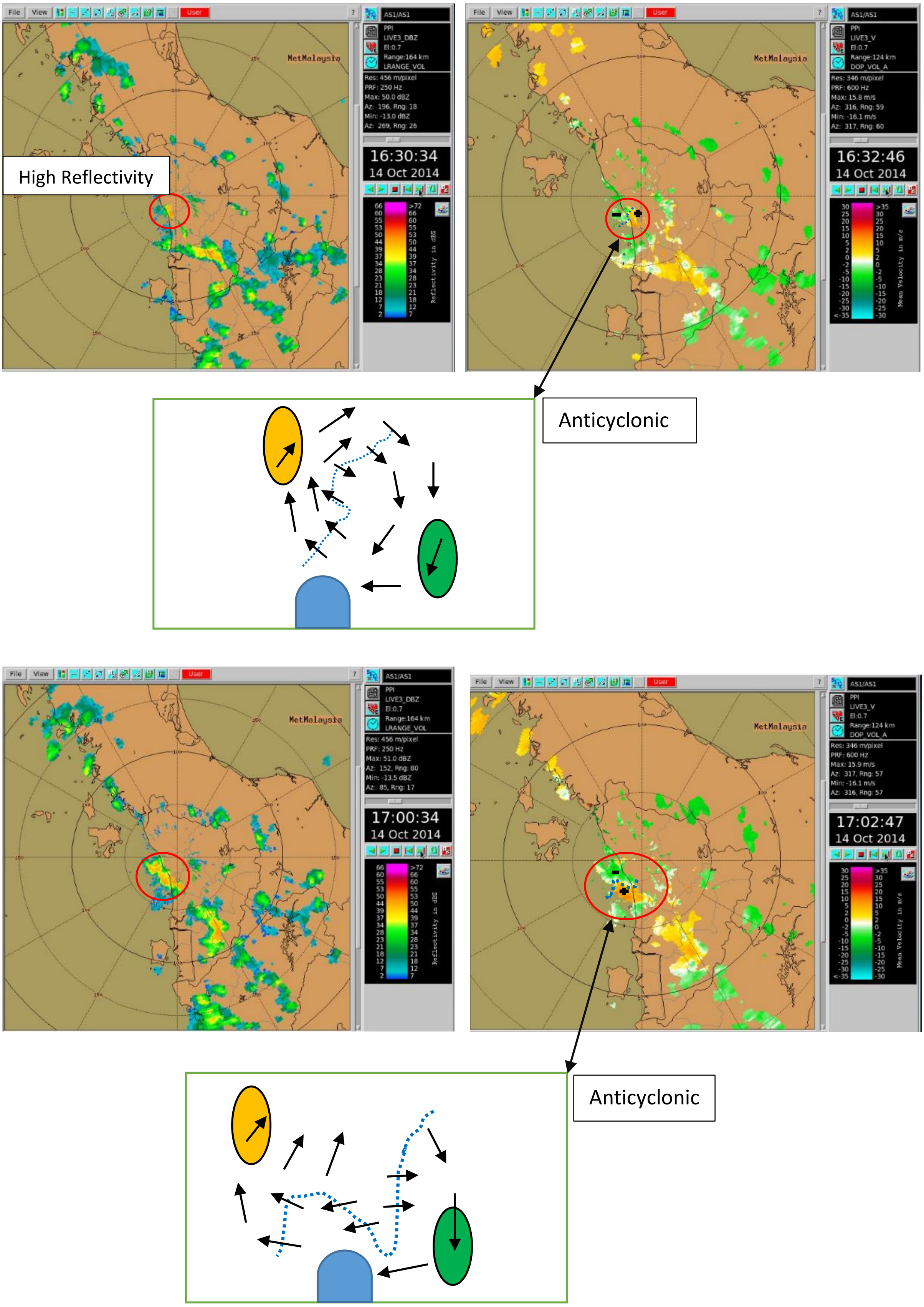


Figure 6: Reflectivity and velocity products in detecting landspout.

The thunderstorm clouds were approaching to the site location from single to multi-cell clouds as shown in Figure 6. Based on reflectivity product, the signature cannot be identified as landspout formation, unless using the velocity product. As shown in the figure above, the anti-cyclonic signature can be detected using the velocity product during the landspout occurrence. Anti-cyclonic signature appeared 30 minutes before the phenomenon and still persisted until 17:00 pm. When making a cross-section using IRIS tool as shown in Figure 7, it shows that cross-sections A display maximum intensity of reflectivity which was in range of 52-54 dBZ. Referring to Table 2, heavy rain was occurred at the location but no hail event was reported. The maximum reflectivity point was located at 5 km height from the ground.

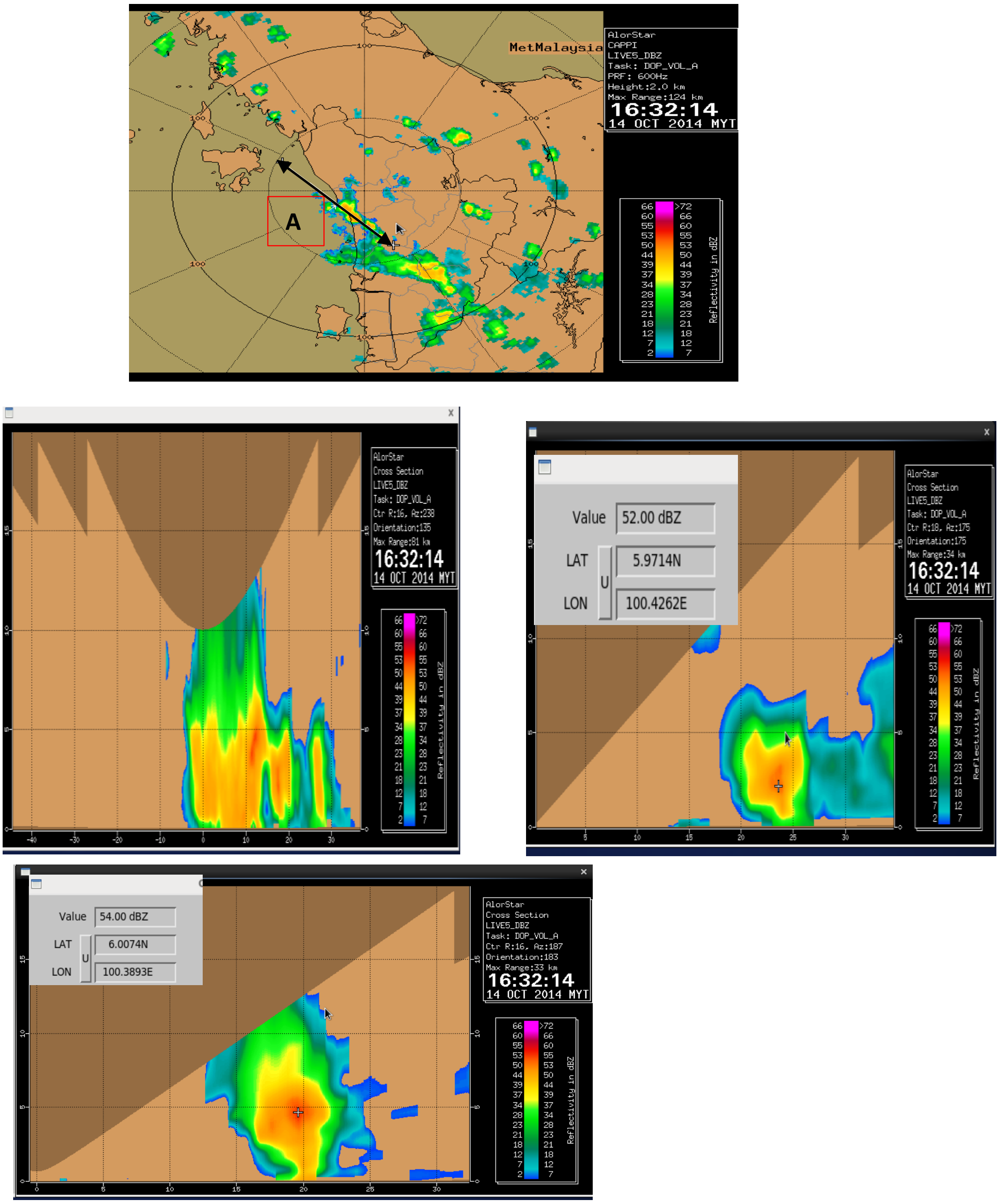
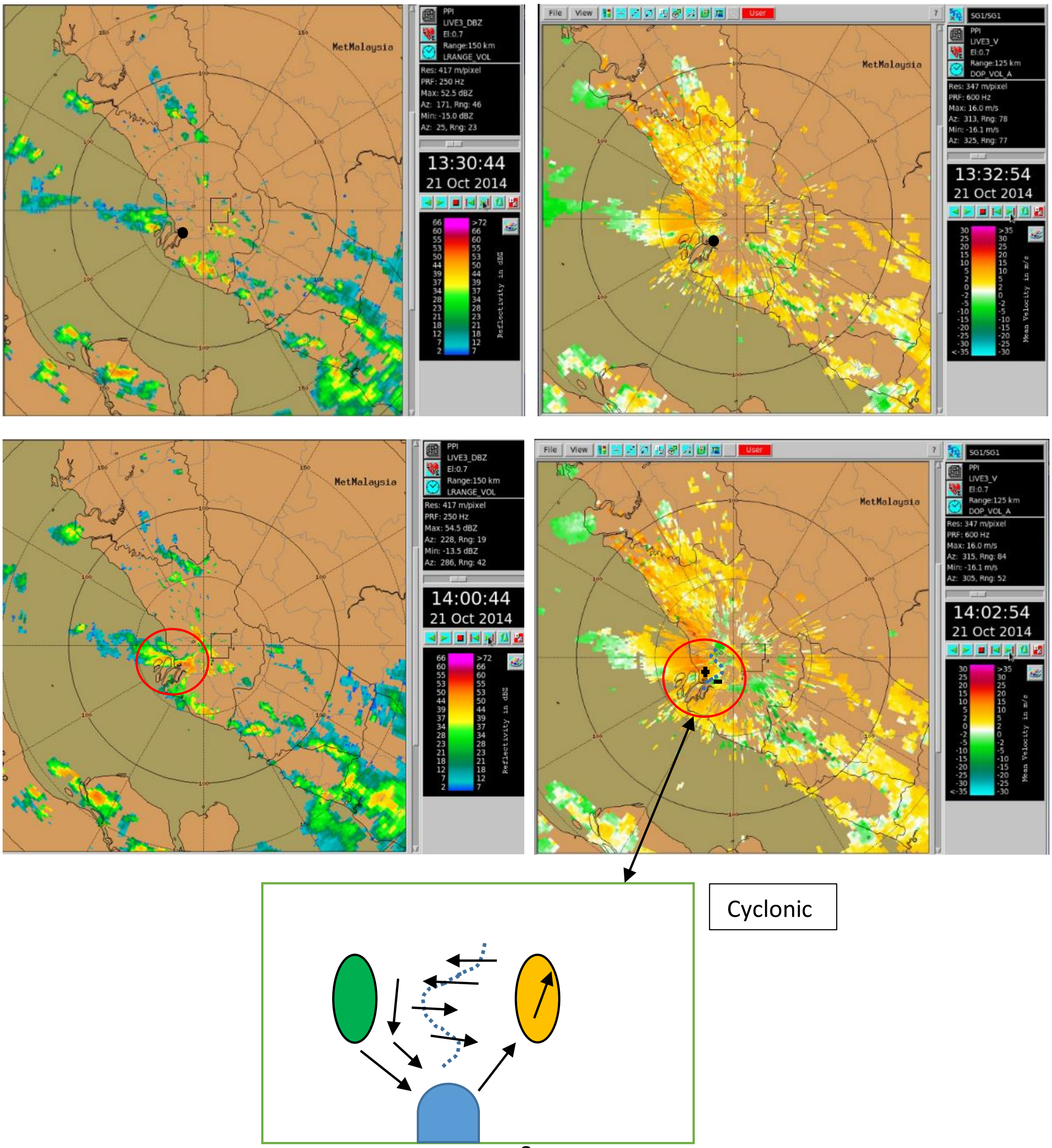


Figure 7: The cross-section of rain echoes view to detect the high reflectivity.

b) 21st October 2014, Pandamaran Selangor (Time:1400pm)

Figure 8: Debris flying in the air during the landspout occurrence at the location



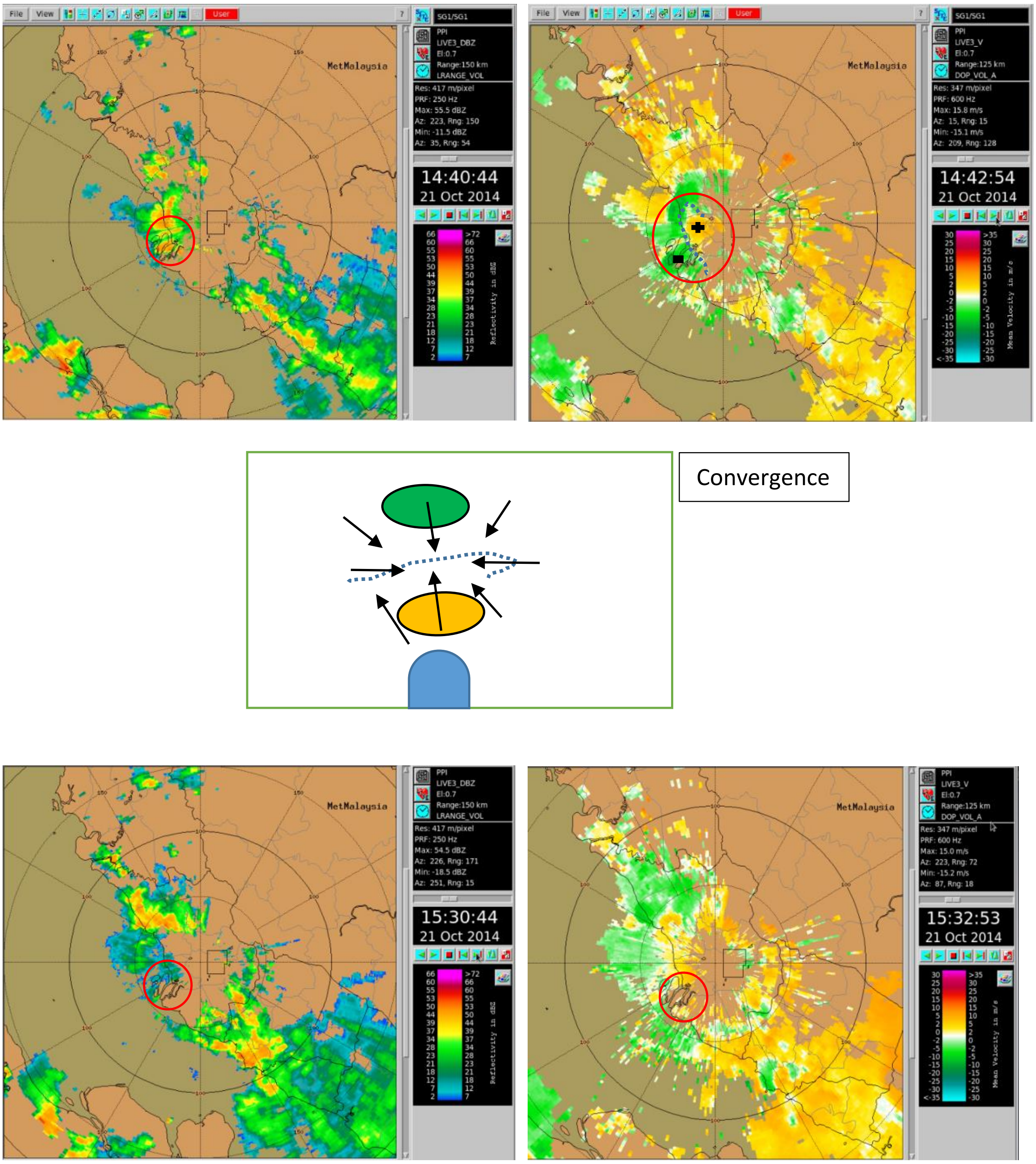


Figure 9: Reflectivity and velocity products in detecting landspout.

As shown in the Figure 9, there are no signature existed before the event occurred. The cyclonic signature can be detected using the velocity product during the landspout occurrence. Convergence signature appeared 40 minutes after the phenomenon indicate that the rain cloud is still developing and there are no signature existed after half and one hour occurrence. These both of signature revealed that the heavy rainfall happened with developing cloud, but the landspout occurrence can be identified from the cyclonic rotation during the event but cannot identified earlier as velocity products can be referred every 30 minutes only.

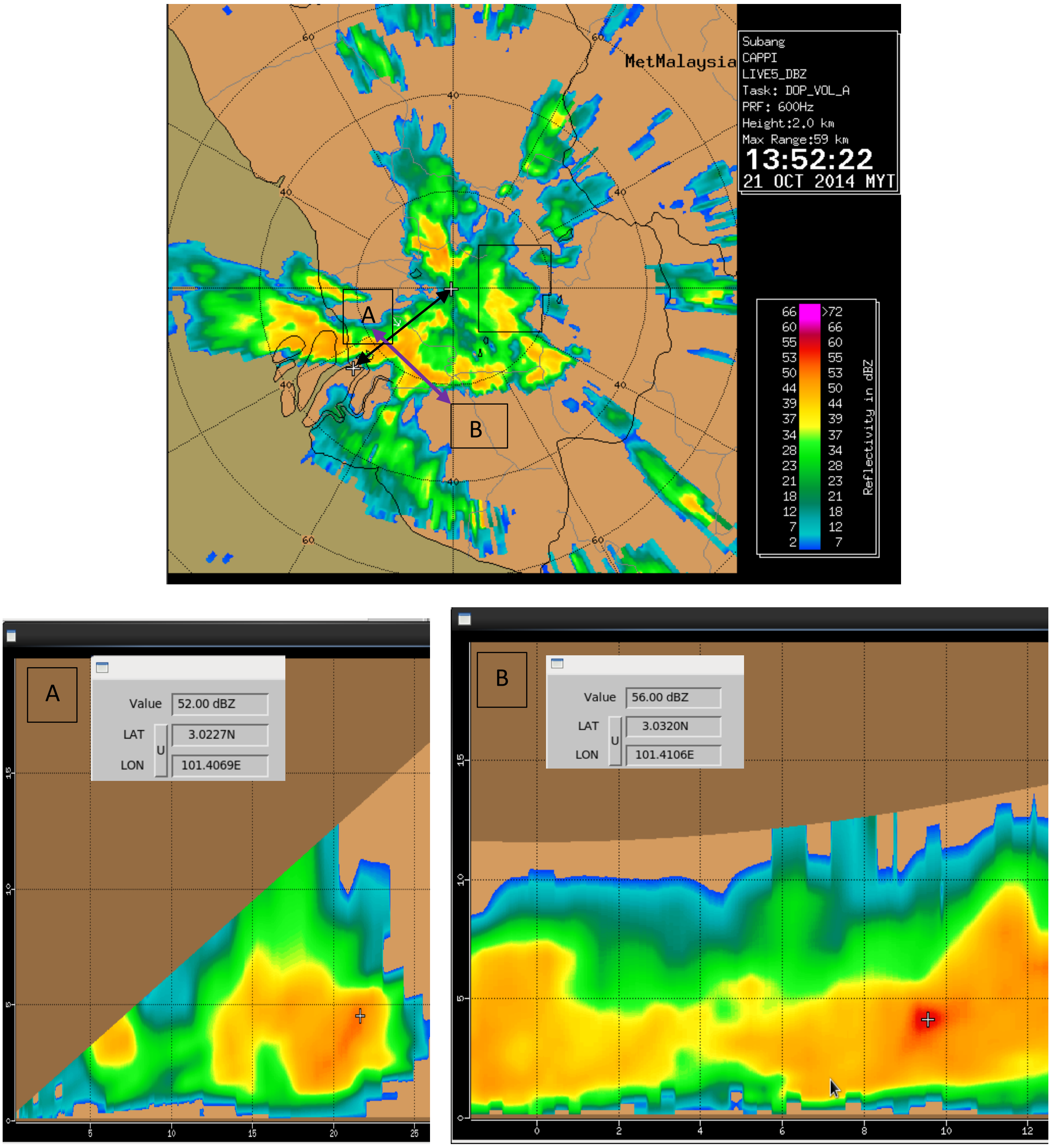
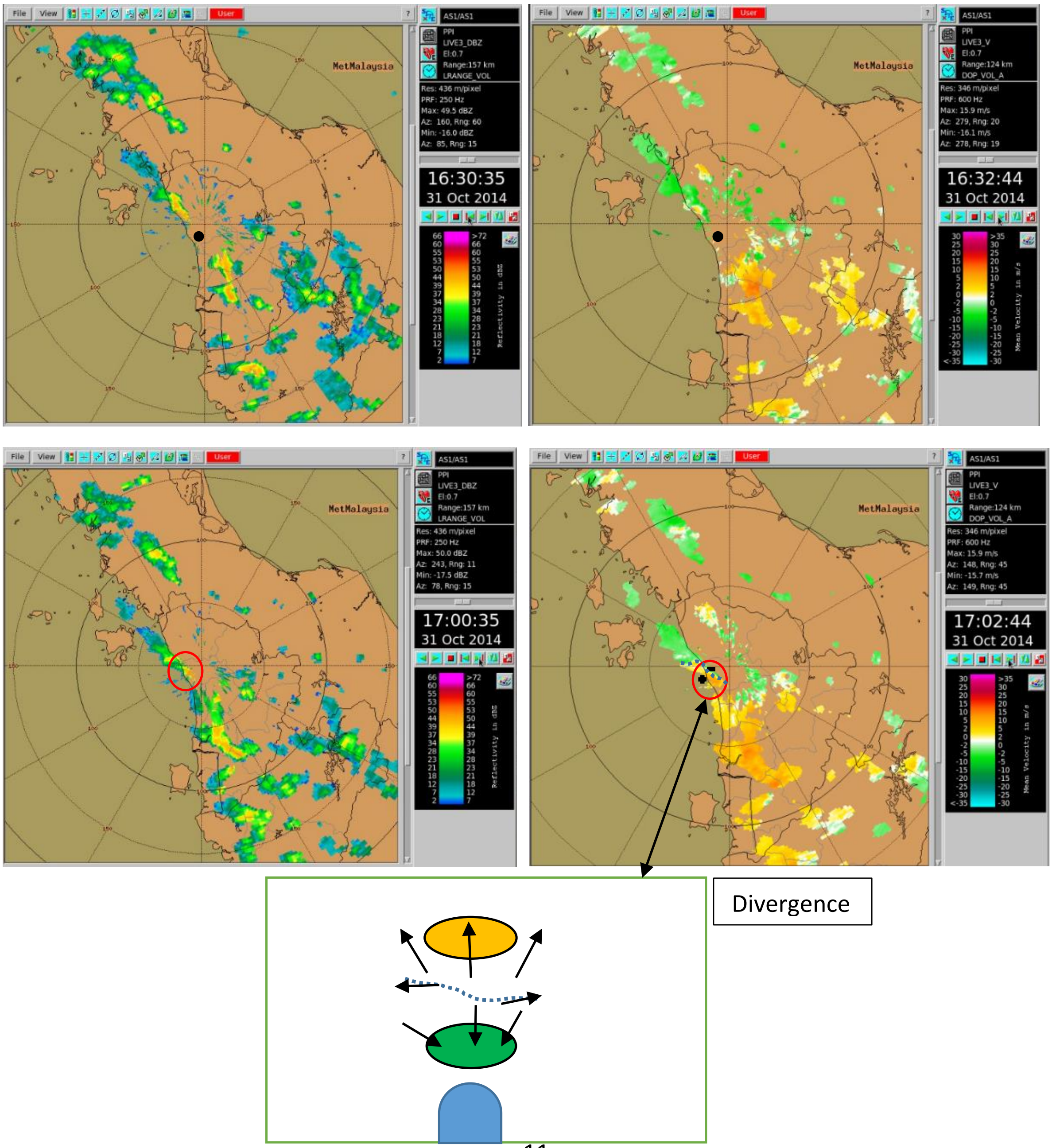


Figure 10: The cross-section of rain echoes view to detect the high reflectivity

During this event, no hail event was reported, only gusting wind and landspout were occurred. When making cross-section using IRIS tool as analysed as figure 10, it shows that cross-section B display maximum reflectivity which was indicated 56 dBZ resulting in very heavy rain or hail phenomenon can be occurred. The maximum reflectivity point was located at near 4 km height from the ground and the height of top cloud was in range of 10-11 km.

c) 31st October 2014, Kota Setar Kedah (Time:1700pm)

Figure 11: The image of landspout at location in Kota Setar, Kedah (Courtesy: Astro Awani)



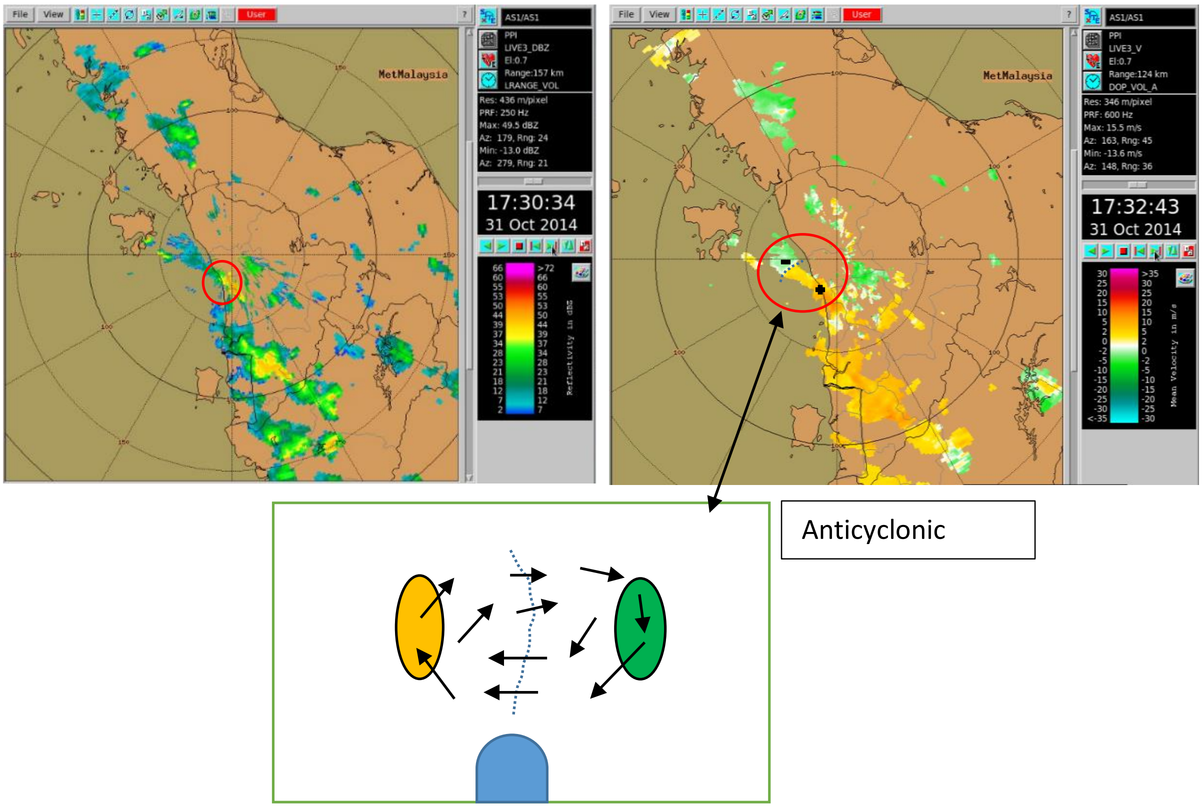
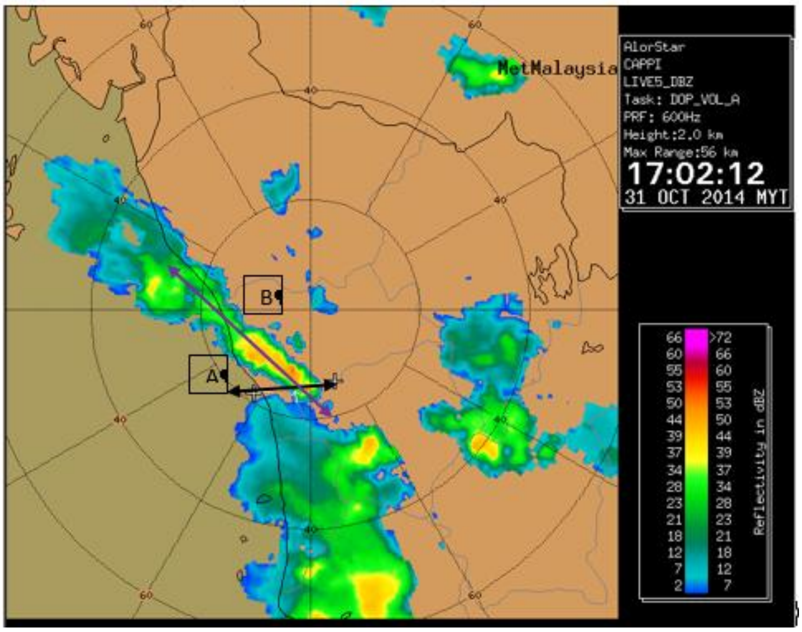


Figure 12: Reflectivity and velocity products in detecting landspout.



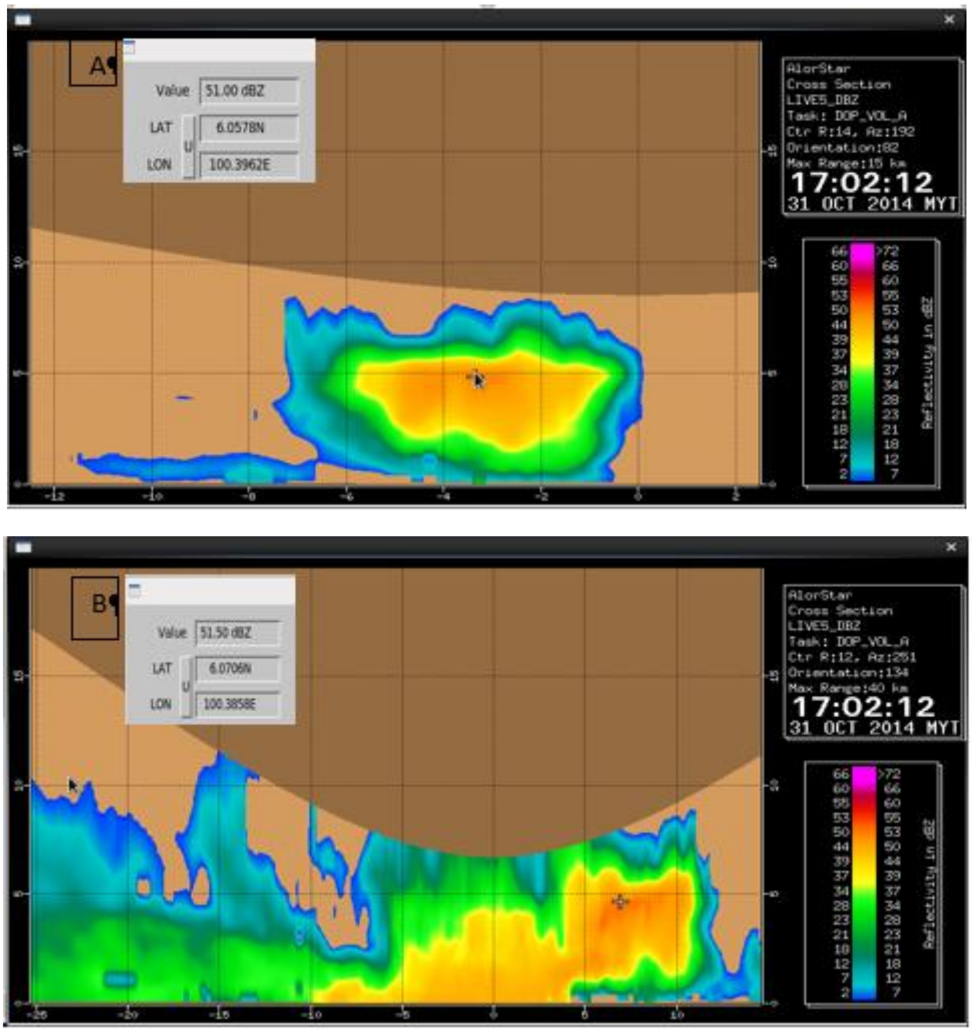
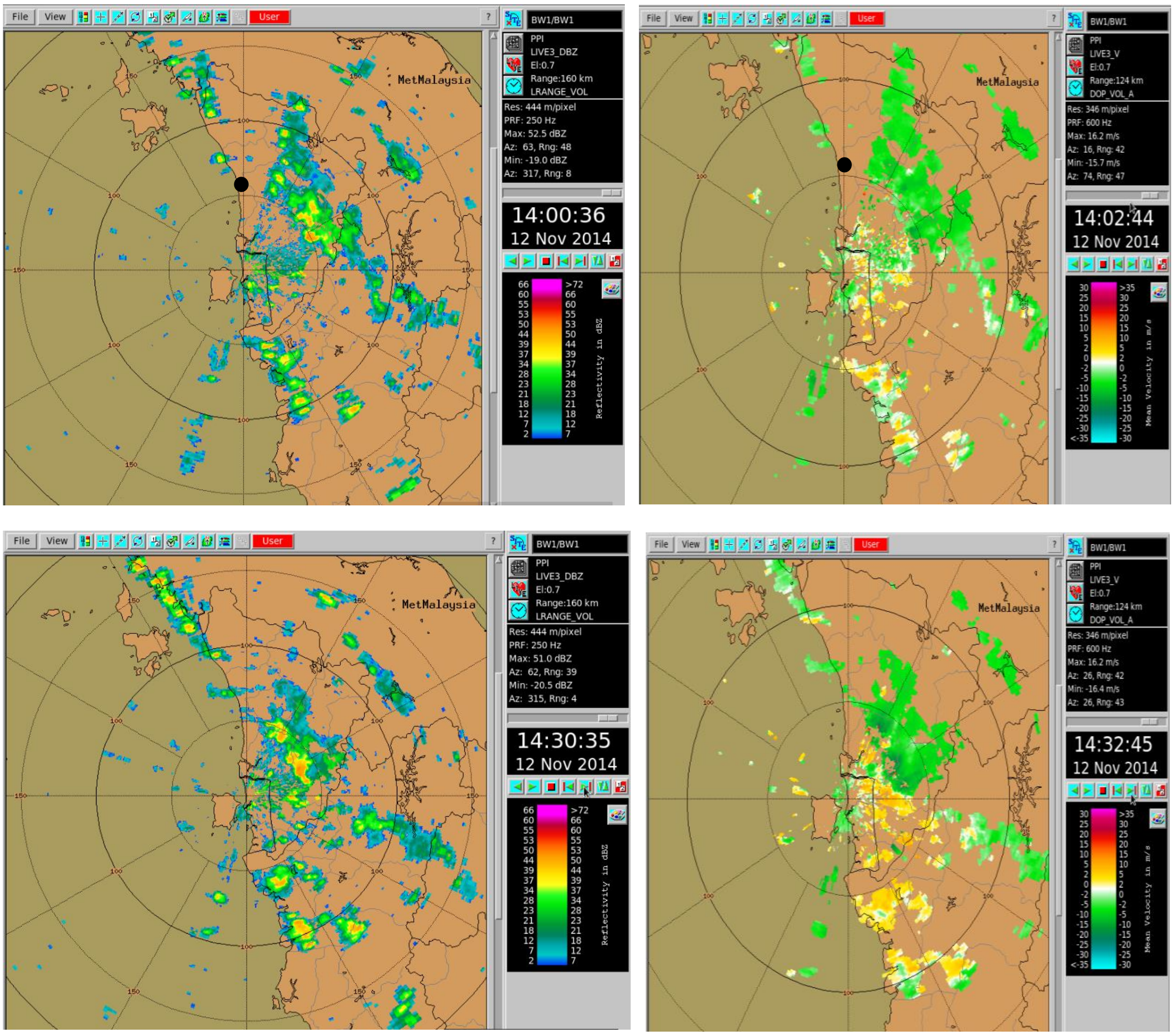


Figure 13: The cross-section of rain echoes view to detect the high reflectivity

Figure 11 describes the landspout phenomena during the event. Based on Figure 12, the rain echoes were generated from single to multiple cells of thunderstorm clouds. These figures described that the landspout was sustained in shorter time. From the velocity products as illustrated in figure above, the divergence signature existed indicated that the downburst occurred during the occurrence and anti-cyclonic signatures after 30 minutes from the occurrence time. Meanwhile, reflectivity products can be explored in details using vertical cross-section as shown in Figure 13. The maximum reflectivity on the cross-section radar echoes is 51 dBZ which shows heavy rainfall occurred at the location which the point is situated at 5 km height from the ground. There are no reported about hail occurrence during this event.

d) 12th November 2014, Kota Sarang Semut Kedah (Time:1500pm)

Figure 14: The image of landspout at location in Kota Sarang Semut, Kedah (Courtesy: Astro Awani)



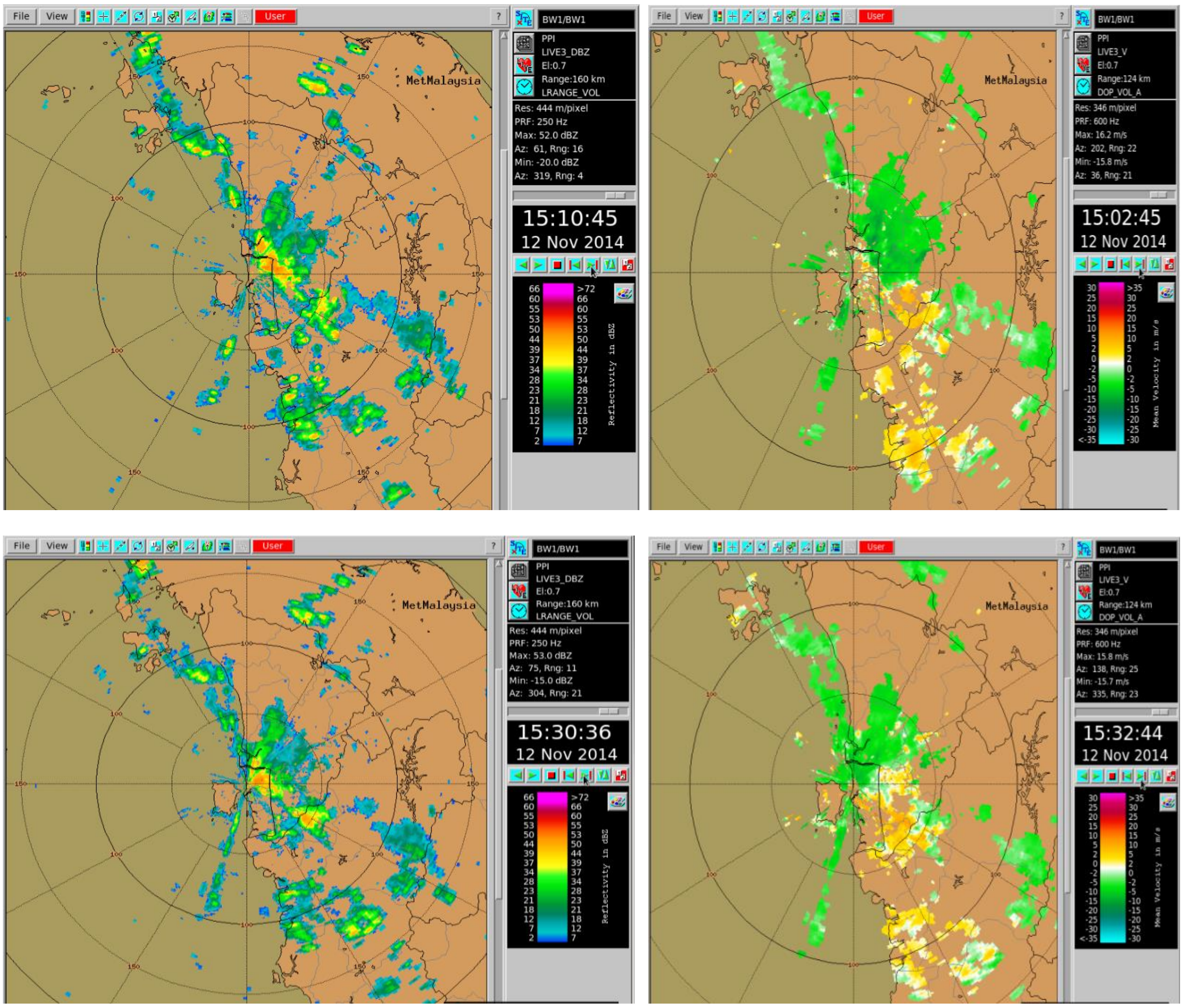
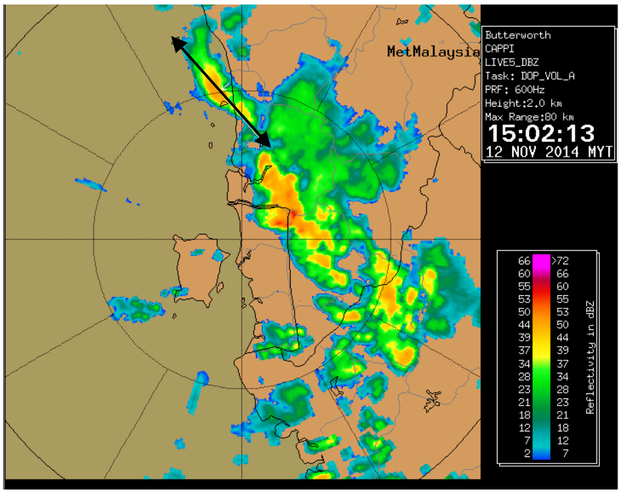
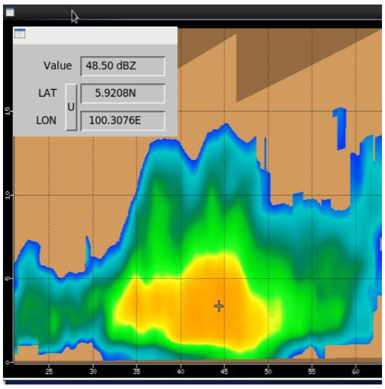


Figure 15: Reflectivity and velocity products in detecting landspout.





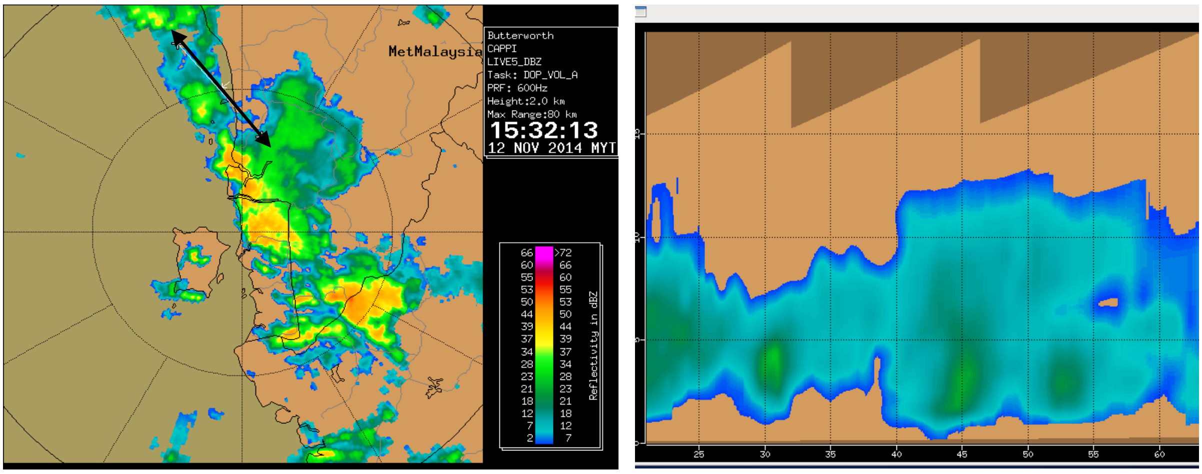


Figure 16: Reflectivity and velocity products in detecting landspout.

The landspout image was described in Figure 14. There are no significant for landspout detection on velocity products as illustrated in Figure 15. The maximum reflectivity is 48.5 dBZ stated at the site which the height of maximum reflectivity is 3 km and the top of cloud can be reached to 14 km as illustrated in Figure 16.

Hail Events

a) 2nd March 2014, Semenyih Selangor (Time:1700pm)

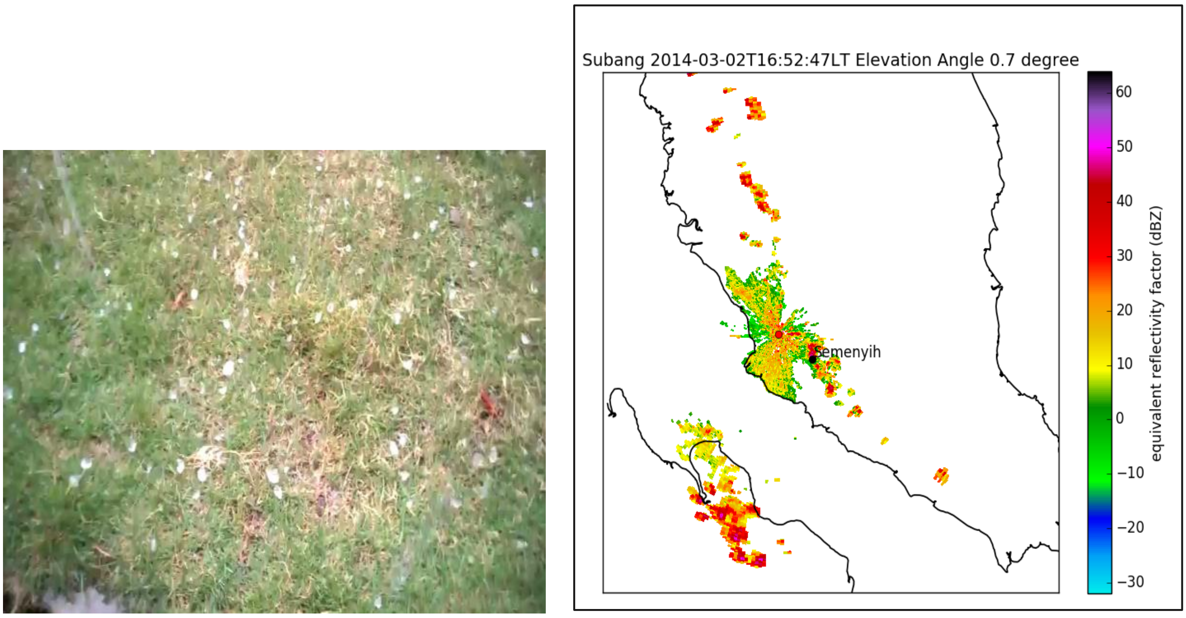
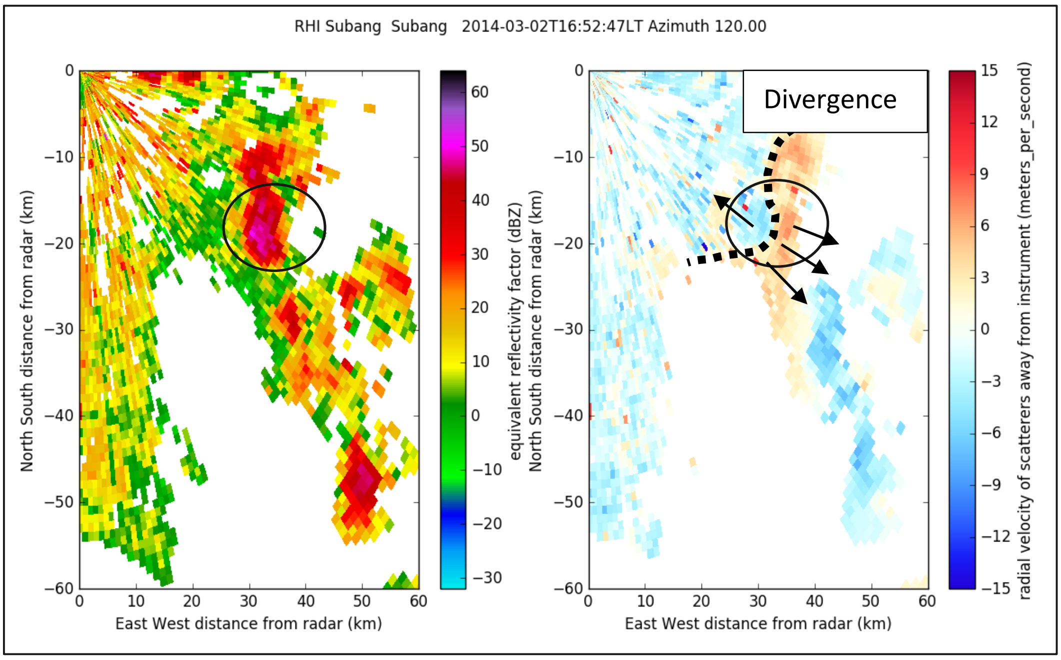
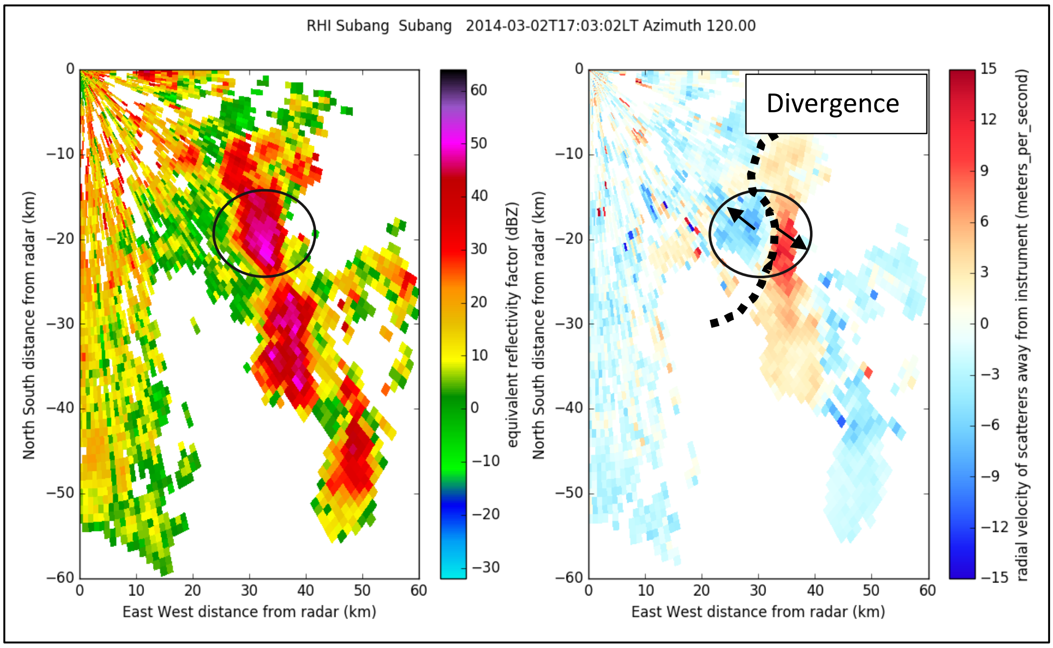


Figure 17: Occurrence of hail and the point of location at Semenyih, Kajang

The location of occurrence is described in Figure 17. Referring to Figure 18, the divergence signature at velocity products existed before and until half an hour after the occurrence. The reflectivity more than 50 dBZ are shown in the cell of echoes. These both of signature revealed that the downburst may indicate the melting of hail when the freezing level located below than the peak dBZ will be discussed below.


RHI Subang Subang 2014-03-02T16:52:47LT Azimuth 120.00
Divergence
North South distance from radar (km)
East West distance from radar (km)
equivalent reflectivity factor (dBZ)
radial velocity of scatterers away from instrument (meters_per_second)


RHI Subang Subang 2014-03-02T17:03:02LT Azimuth 120.00
Divergence
North South distance from radar (km)
East West distance from radar (km)
equivalent reflectivity factor (dBZ)
radial velocity of scatterers away from instrument (meters_per_second)

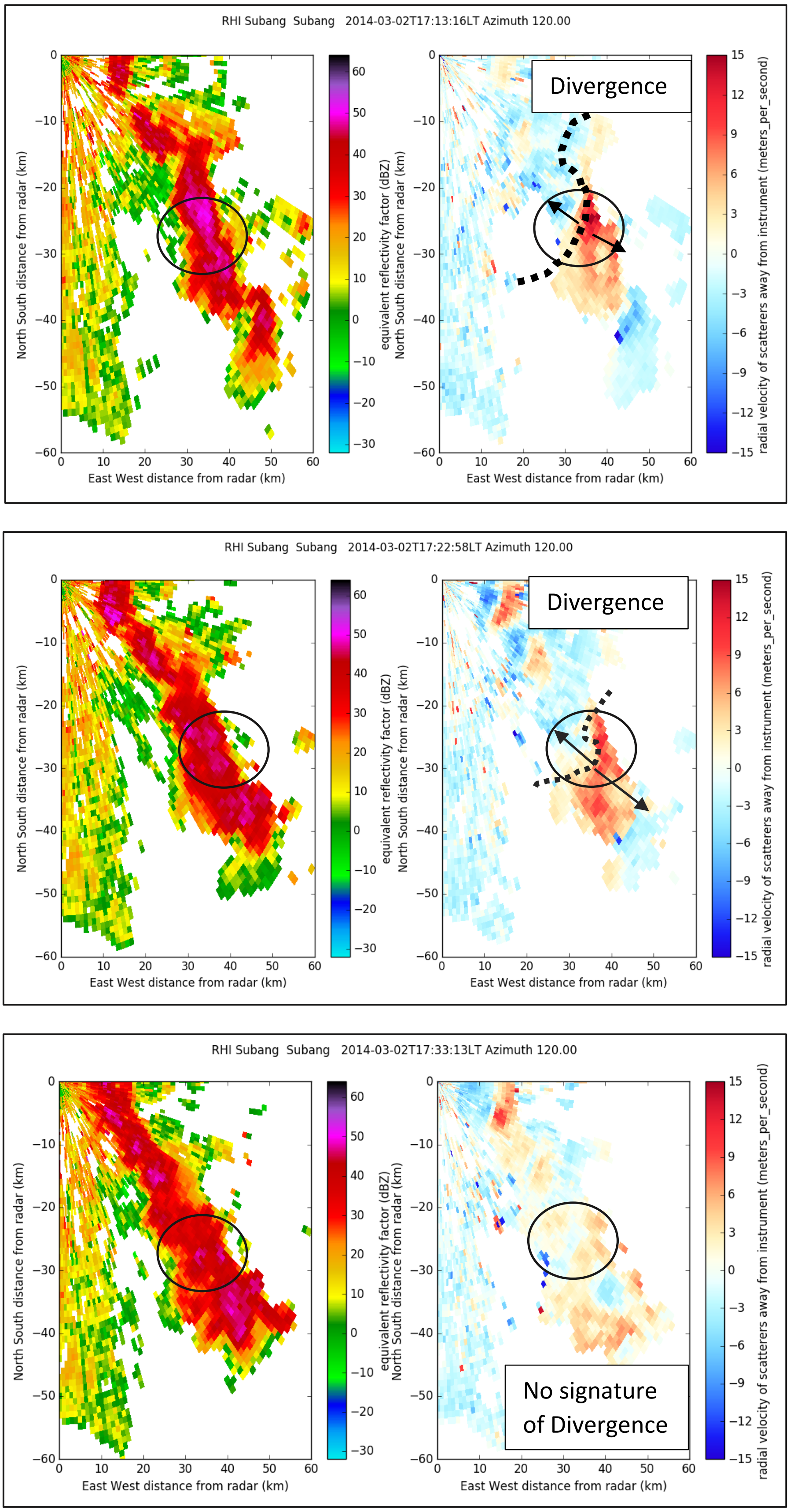


Figure 18: PPI scans at base reflectivity (0.7 degree) for reflectivity and velocity products

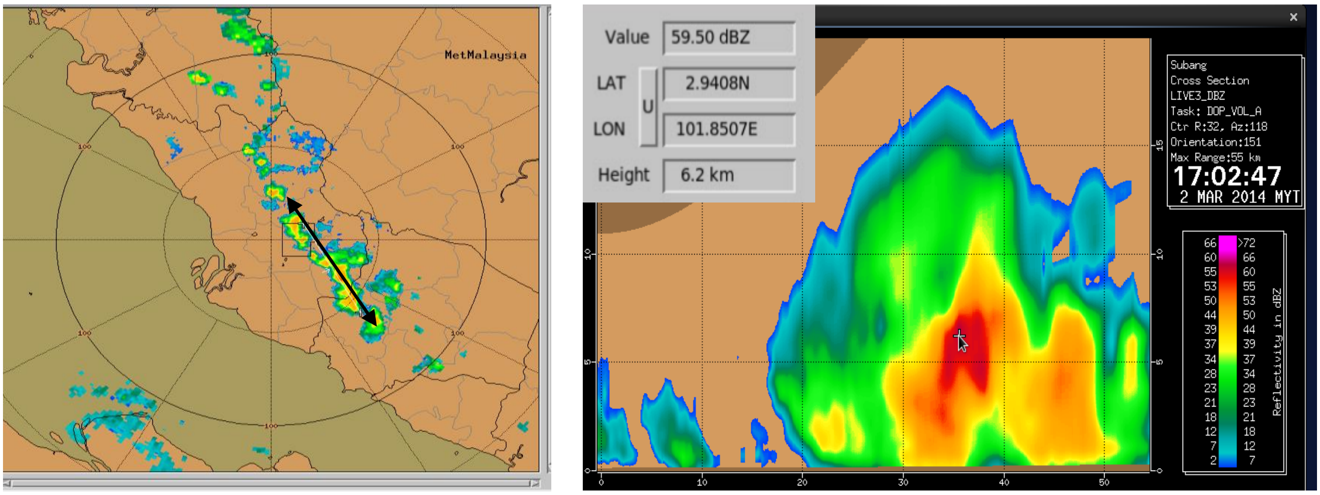


Figure 19: The cross-section of rain echoes view to detect the high reflectivity

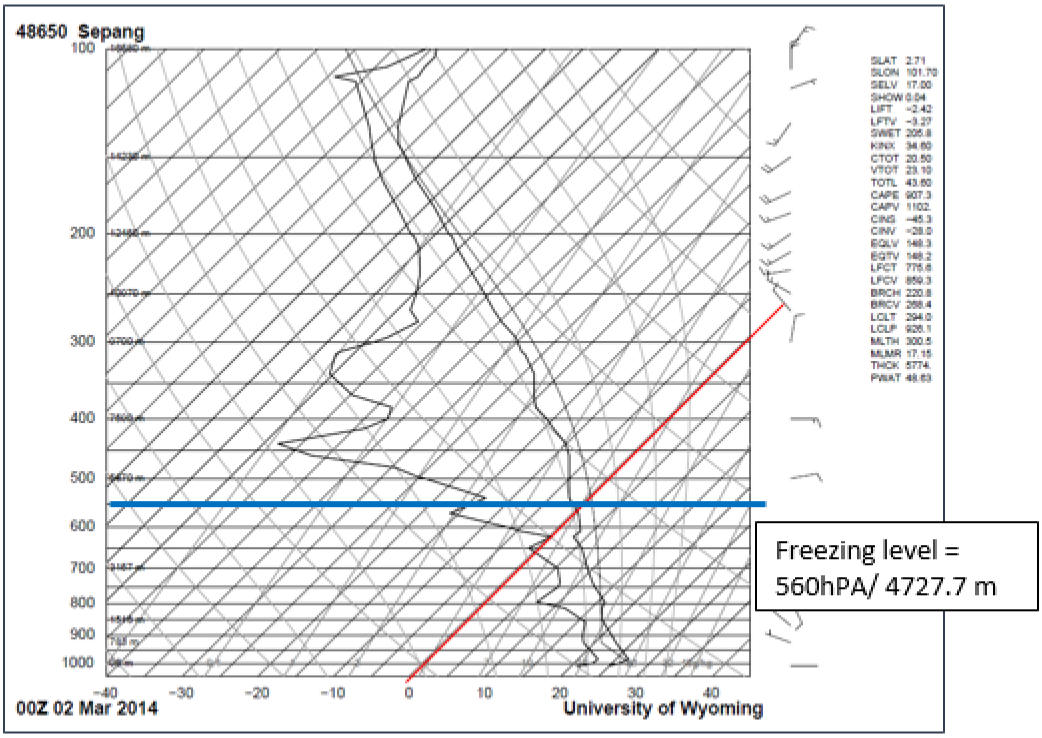


Figure 20: Radiosonde data with the freezing level at 560 hPa (4727.7m)

As shown in Figure 19, the maximum reflectivity during the event was 59.50 dBZ (peak dBZ) meanwhile the top of echo cloud was 18 km. The point of maximum reflectivity is located at 6.2 km height from the ground when making reflectivity vertical cross-section at the location using volume scan A of CAPPI which is consisted of elevation angle 0.0, 0.7, 1.5 and 2.5 degree. Additionally, the reflectivity values between 53-55 dBZ is located between 4-6 km from the ground. The freezing level values illustrated in Figure 20 during the event was 560 hPa (4.7km) which the thunderstorm clouds produced hails at the area.

b) 7th August 2015, Bandar Jengka, Pahang (Time:1730pm)

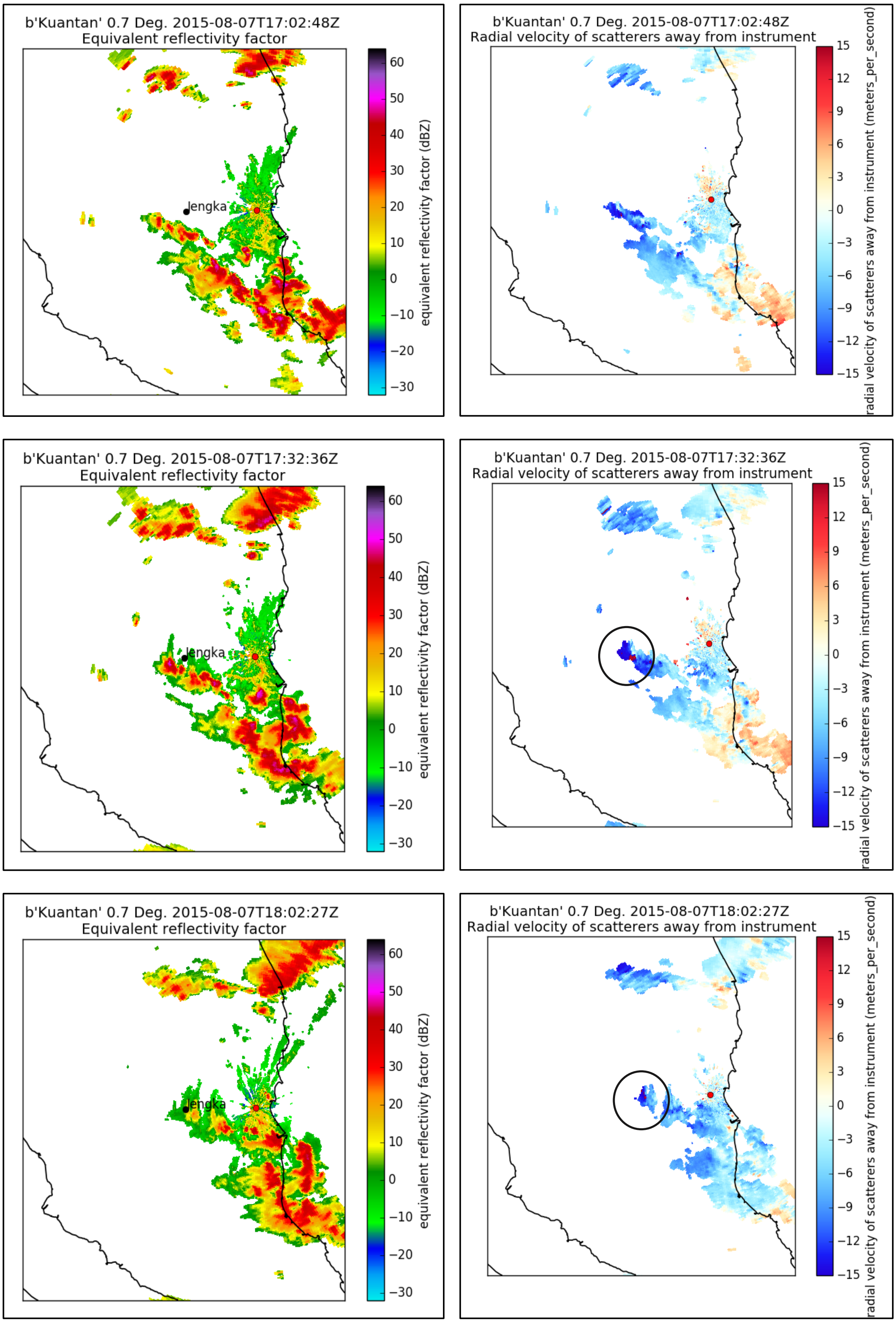


Figure 21: Reflectivity and velocity products at PPI 0.7 elevation angle.

Black circle as described in Figure 21 is indicated aliasing. Aliasing is occurred when the radar's maximum unambiguous velocity is lower than the maximum radial velocity that is occurred at the site. This is depend on the pulse repetition frequency (PRF) which this problem is known as Doppler Dilemma. Kuantan Radar Station is S-band radar with PRF 600 Hz. The calculation to calculate Vmax :-

$$V_{max} = \frac{PRF \times \lambda}{4} => \frac{600 \times 0.10m}{4} = 15 m/s$$

In Doppler Dilemma, the radar will interpret as a weaker wind when the environmental wind exceeds the maximum unambiguous velocity. For example, in this case Vmax is 15 m/s and environmental wind speed are larger than this Vmax caused the interpretation of radar such as in the black circle. Basically, this will happen when using a shorter wavelength radar in the situation of very strong wind and wind shear. This case indicated the strong wind happened at that areas that hail occurred. Hence, Range Height Indicator (RHI) is analysed to reveal the signature hail occurrence as shown in Figure 22. The reflectivity and velocity in the black circle respectively point out the dBZ value more than 50 and cyclonic signature existed. Therefore, the location of this severe thunderstorms can produce very strong winds and possibility of hail occurrence.

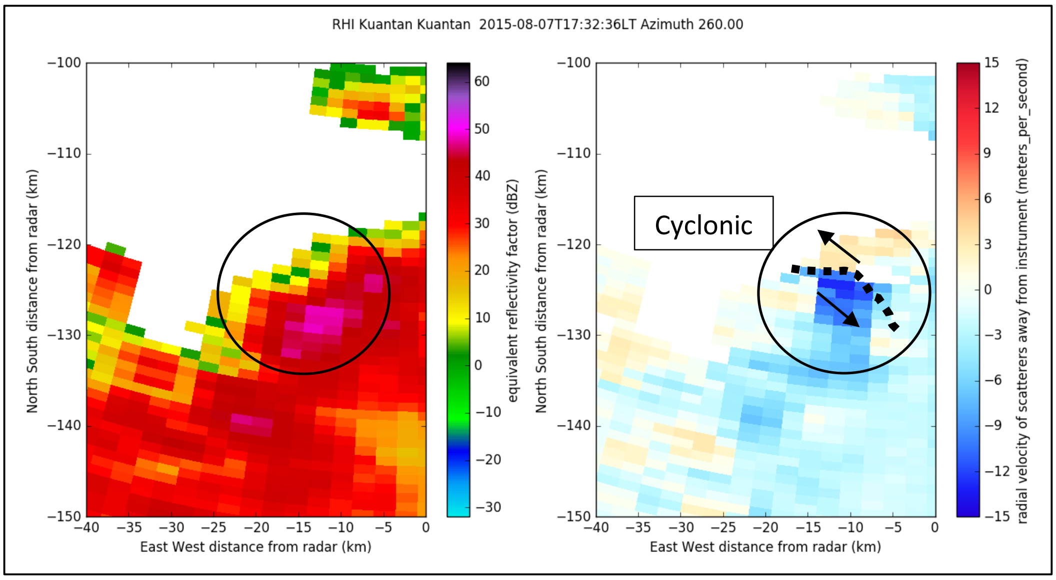


Figure 22: RHI scans (260◦ azimuth) at 17:32LT at Jengka area.

To analyse in details, the vertical cross-section of reflectivity should be done by forecasters to recognize the hail target. According to the time occurrence at 1730 pm from Figure 23, the top of echoes about 20-25 km height while the maximum reflectivity is situated at 5.7 km with 56 dBZ value. From these images, the developing storm produced hails which the range of reflectivity of 55-60 dBZ is built up at the height of 10-12 km from the ground. After 30 minutes of occurrence, the maximum reflectivity (58 dBZ) was occurred at 18:00 pm which the top of clouds is reached to 15-18 km height and the point of maximum is situated at 4.1 km from the ground. In comparison with the radiosonde data at Figure 24, the freezing level is 4.6 km height. The hail occurrence during this event is depended upon the freezing level and the peak reflectivity from the ground level.

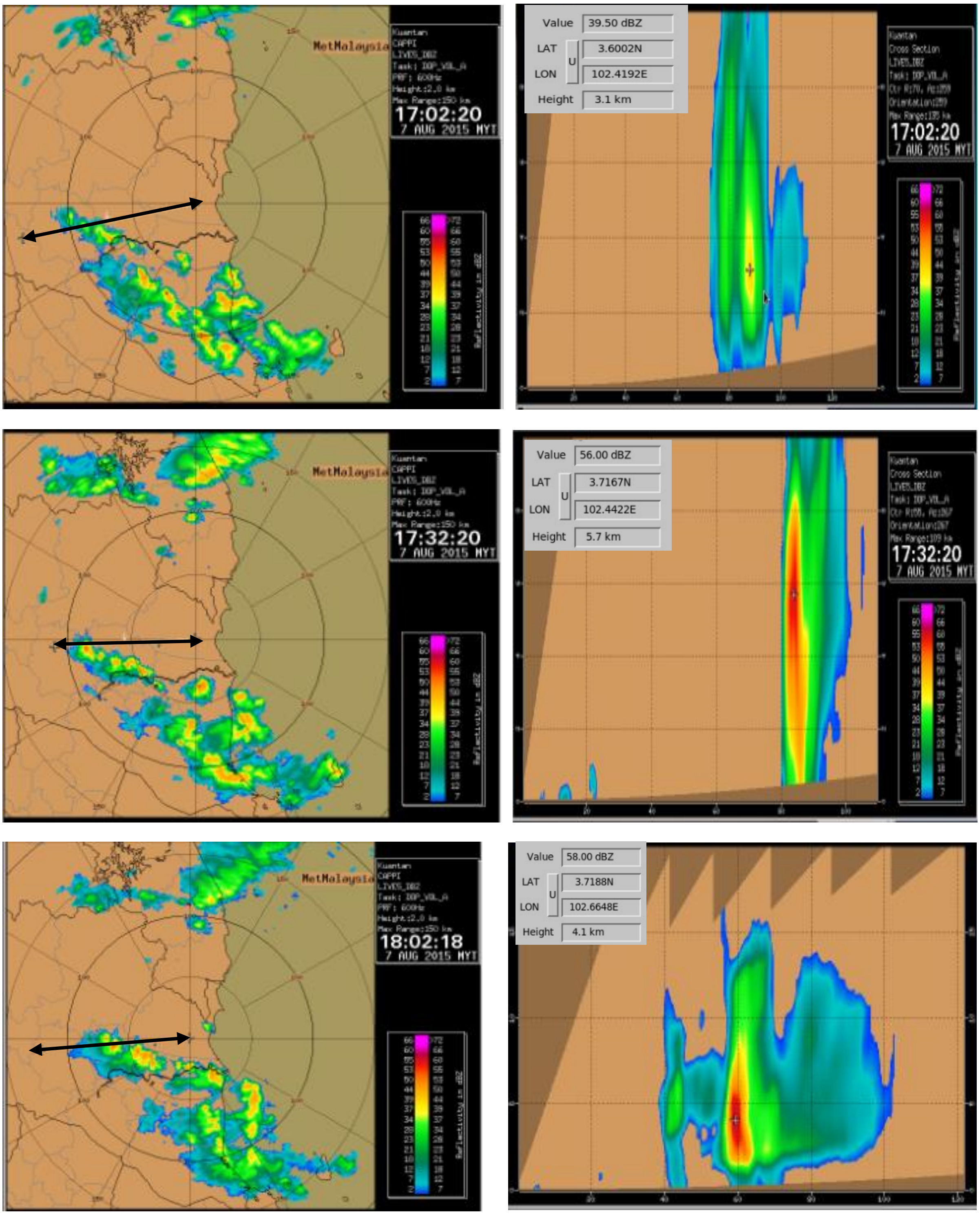


Figure 23: Reflectivity and velocity products in detecting hail.

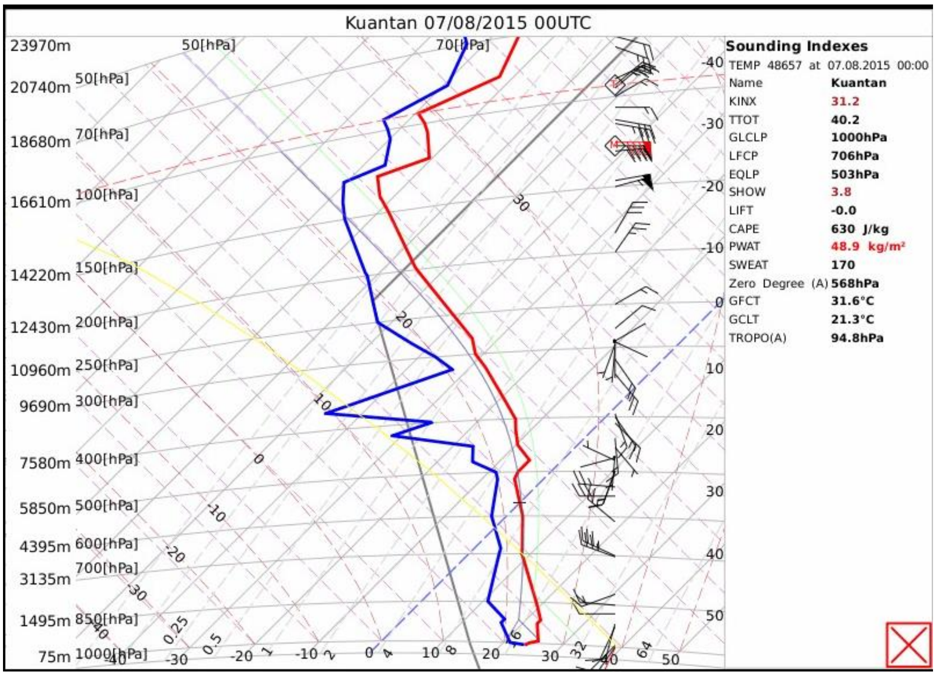
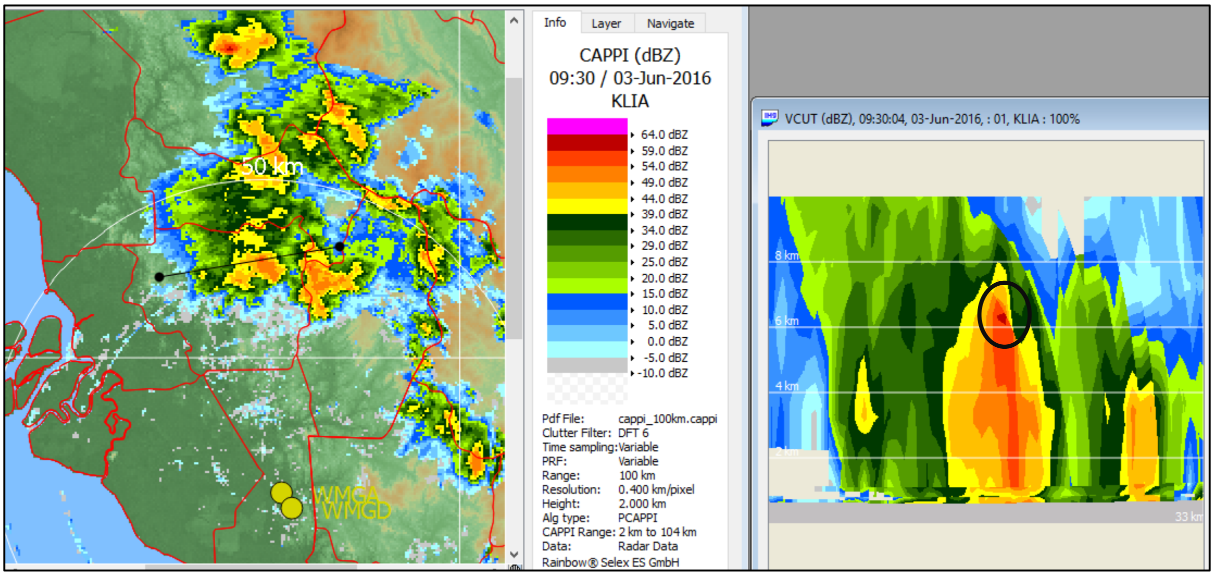
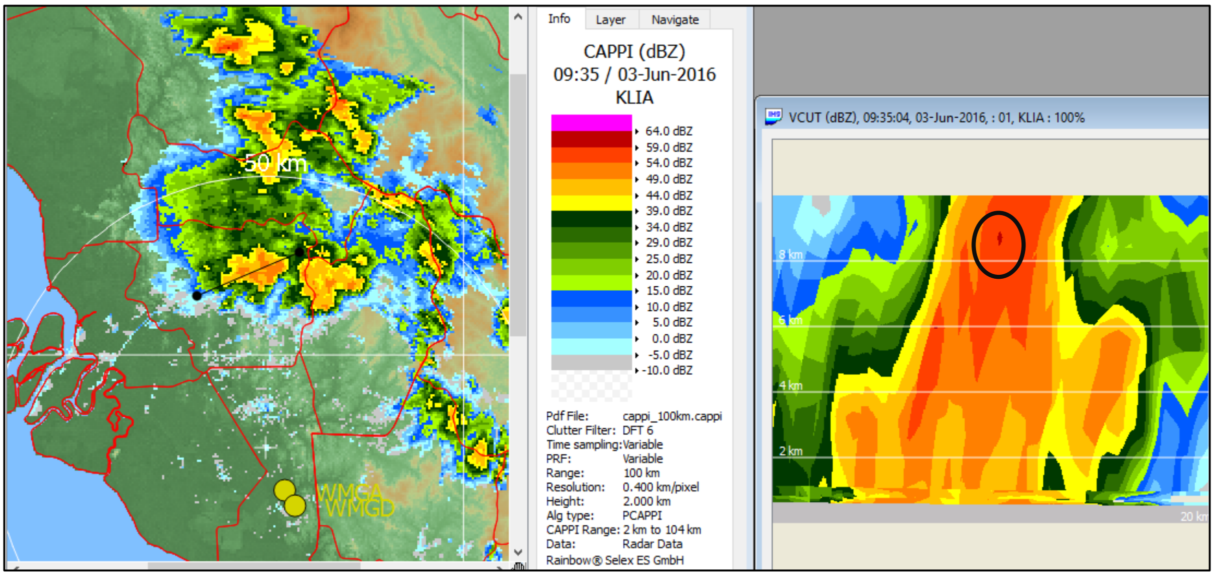


Figure 24: Radiosonde data which freezing level is located at 568 hPA (4620.7m) height.

c) 3rd June 2016, Bukit Jalil, Kuala Lumpur (Time:1800pm)

Subang radar data station were changed to Airport Mode, hence the coverage not reach to the location. KLIA radar station has the capability to produce the data regarding on this event. Distance form KLIA radar to location event is 23.65 km. Time display in KLIA images are in UTC Time by using RAINBOW software. As shown in Figure 25, the maximum reflectivity, 59 dBZ and 64 dBZ were detected at the height of 6.1 km at 17:30 pm and 17:40 pm respectively. From the figure, the maximum reflectivity at range 64 dBZ value were detected until 18:15 pm resulting in the severe storms and large hail at the location as illustrated in Figure 26. Mesocyclone signature was existed during the event and the maximum velocity was detected at the area. The reflectivity more than 55 dBZ not existed at 18:30 pm.

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09:35 / 03-Jun-2016
KLIA
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44.0 dBZ
39.0 dBZ
34.0 dBZ
29.0 dBZ
25.0 dBZ
20.0 dBZ
15.0 dBZ
10.0 dBZ
5.0 dBZ
0.0 dBZ
-5.0 dBZ
-10.0 dBZ
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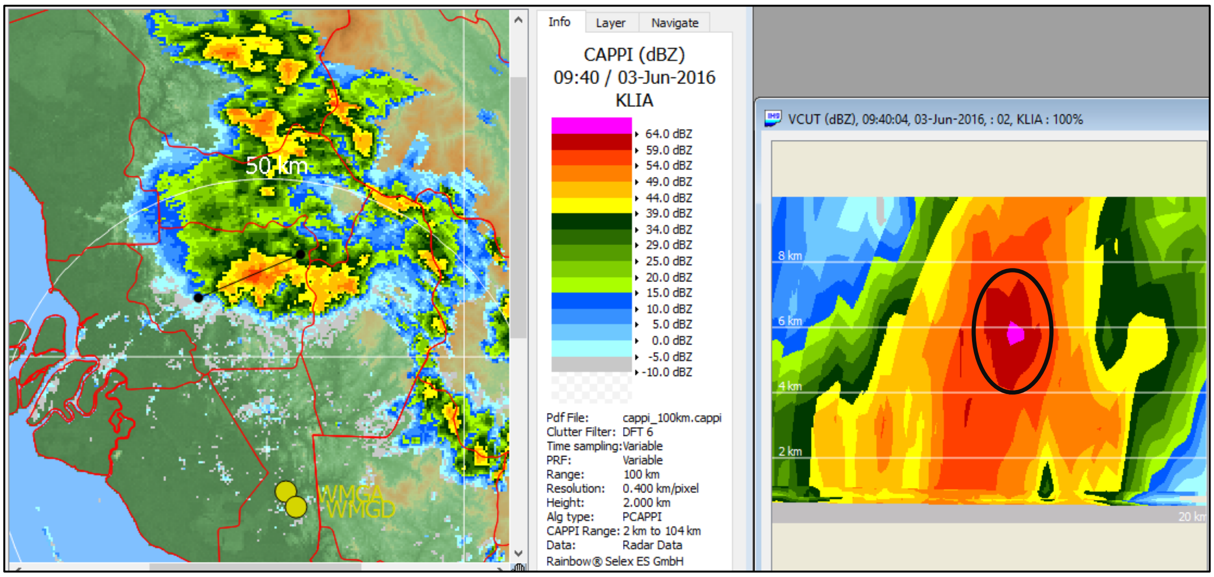
Time sampling: Variable
PRF: Variable
Range: 100 km
Resolution: 0.400 km/pixel
Height: 2.000 km
Alg type: PCAPPI
CAPPI Range: 2 km to 104 km
Data: Radar Data
Rainbow® Selex ES GmbH
50 km
WMCA
WMGD
VCUT (dBZ), 09:35:04, 03-Jun-2016, : 01, KLIA : 100%
8 km
6 km
4 km
2 km
20 km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-5.0 dBZ
-10.0 dBZ
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CAPPI Range: 2 km to 104 km
Data: Radar Data
Rainbow® Selex ES GmbH
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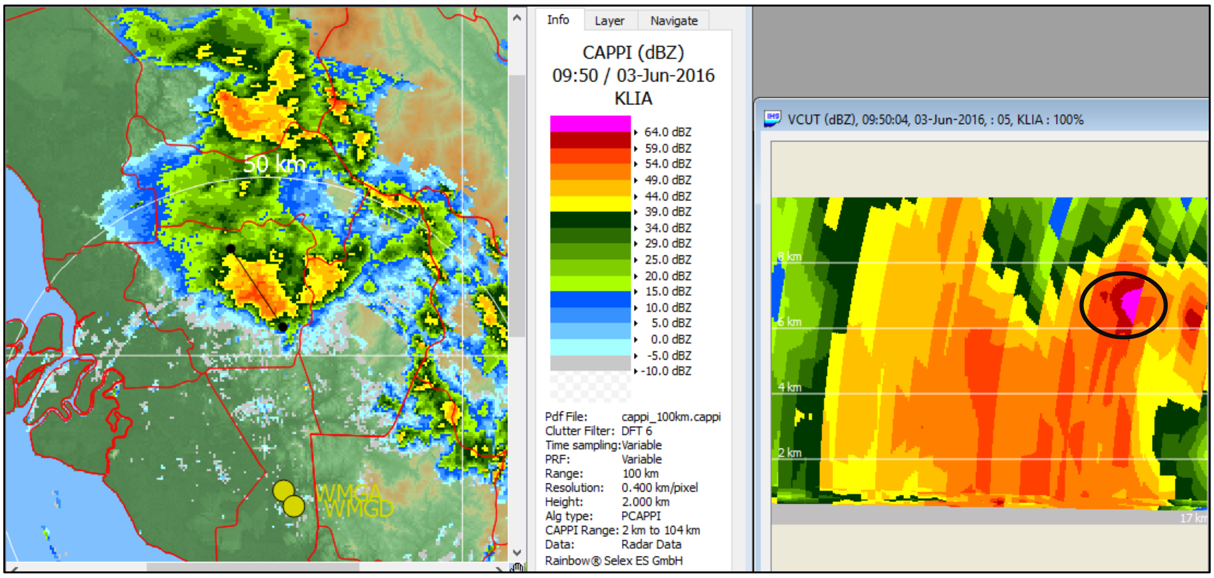
20 km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29.0 dBZ
25.0 dBZ
20.0 dBZ
15.0 dBZ
10.0 dBZ
5.0 dBZ
0.0 dBZ
-5.0 dBZ
-10.0 dBZ
Pdf File: cappi_100km.cappi
Clutter Filter: DFT 6
Time sampling: Variable
PRF: Variable
Range: 100 km
Resolution: 0.400 km/pixel
Height: 2.000 km
Alg type: PCAPPI
CAPPI Range: 2 km to 104 km
Data: Radar Data
Rainbow® Selex ES GmbH
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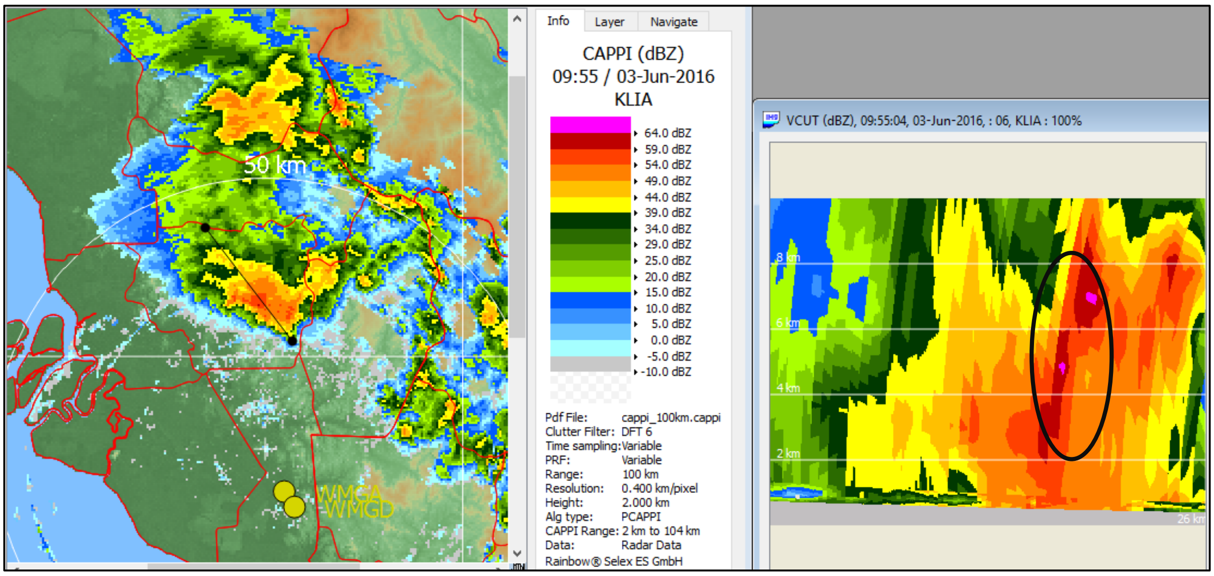
WMCA
WMGD
VCUT (dBZ), 09:50:04, 03-Jun-2016, : 05, KLIA : 100%
8 km
6 km
4 km
2 km
17 km


50 km
WMGA
WMGD
Info
Layer
Navigate
CAPPI (dBZ)
09:55 / 03-Jun-2016
KLIA
64.0 dBZ
59.0 dBZ
54.0 dBZ
49.0 dBZ
44.0 dBZ
39.0 dBZ
34.0 dBZ
29.0 dBZ
25.0 dBZ
20.0 dBZ
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-10.0 dBZ
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Clutter Filter: DFT 6
Time sampling: Variable
PRF: Variable
Range: 100 km
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Alg type: PCAPPI
CAPPI Range: 2 km to 104 km
Data: Radar Data
Rainbow® Selex ES GmbH
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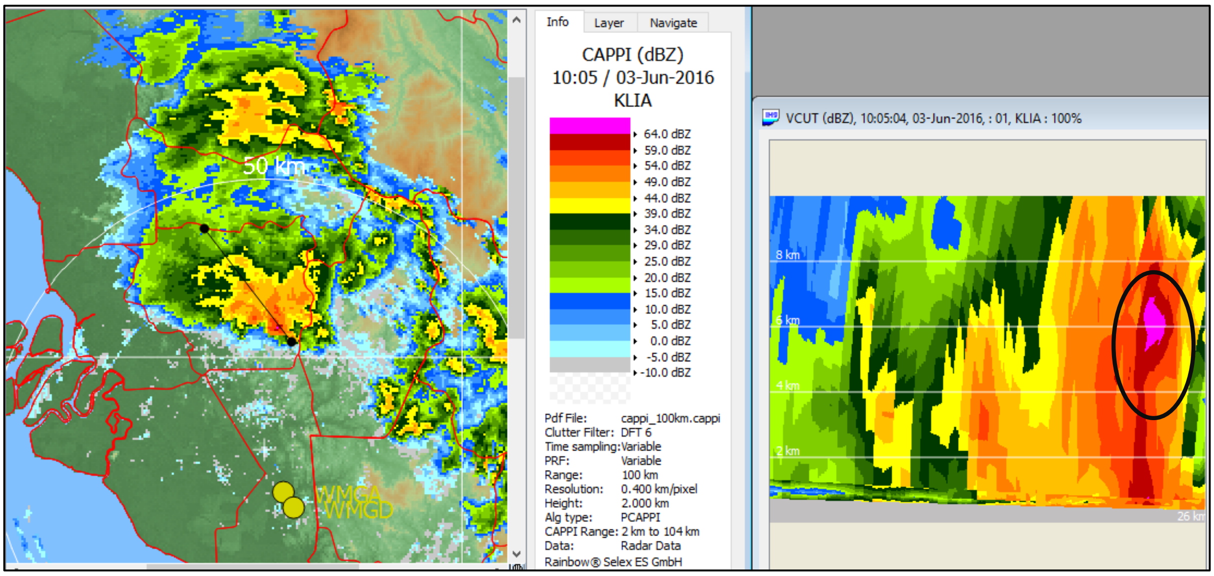
8 km
6 km
4 km
2 km
26 km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WMGA
WMGD
Info
Layer
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10:05 / 03-Jun-2016
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34.0 dBZ
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5.0 dBZ
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-10.0 dBZ
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Clutter Filter: DFT 6
Time sampling: Variable
PRF: Variable
Range: 100 km
Resolution: 0.400 km/pixel
Height: 2.000 km
Alg type: PCAPPI
CAPPI Range: 2 km to 104 km
Data: Radar Data
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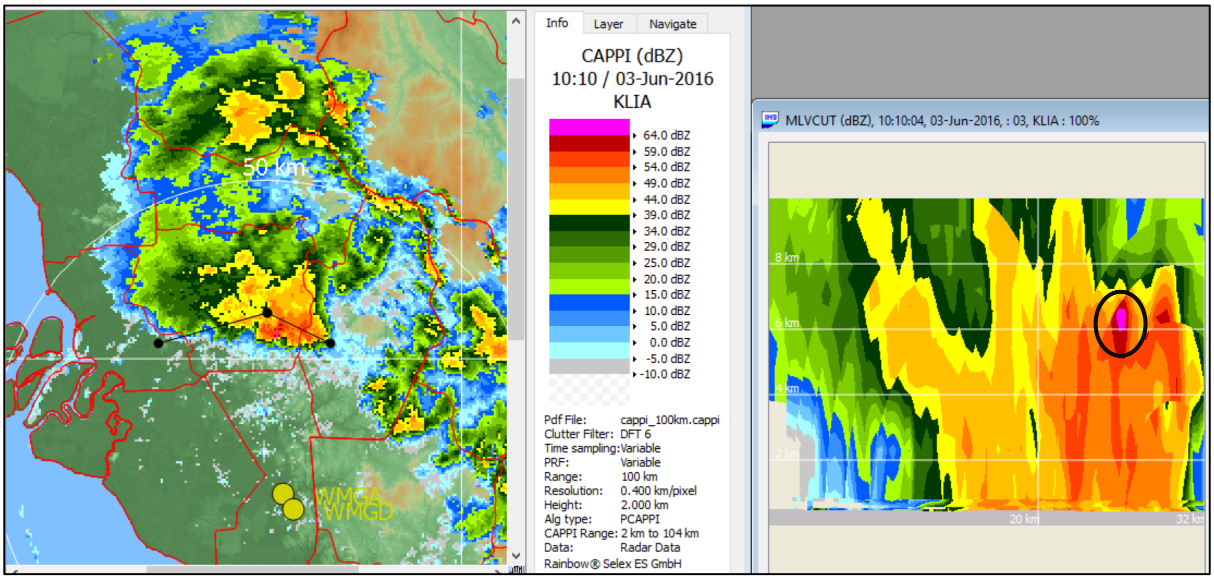
VCUT (dBZ), 10:05:04, 03-Jun-2016, : 01, KLIA : 100%
8 km
4 km
2 km
26 km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WMGA
WMGD
Info
Layer
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10:10 / 03-Jun-2016
KLIA
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54.0 dBZ
49.0 dBZ
44.0 dBZ
39.0 dBZ
34.0 dBZ
29.0 dBZ
25.0 dBZ
20.0 dBZ
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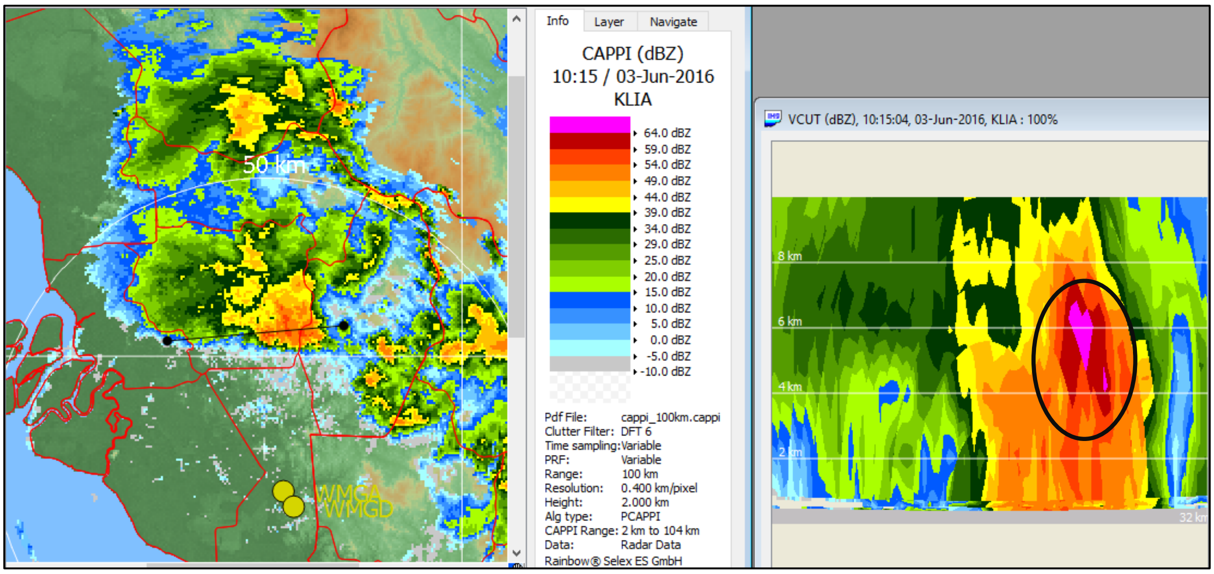
5.0 dBZ
0.0 dBZ
-5.0 dBZ
-10.0 dBZ
Pdf File: cappi_100km.cappi
Clutter Filter: DFT 6
Time sampling: Variable
PRF: Variable
Range: 100 km
Resolution: 0.400 km/pixel
Height: 2.000 km
Alg type: PCAPPI
CAPPI Range: 2 km to 104 km
Data: Radar Data
Rainbow® Selex ES GmbH
MLVCUT (dBZ), 10:10:04, 03-Jun-2016, : 03, KLIA : 100%
8 km
6 km
2 km
20 km
32 km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Layer
Navigate
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34.0 dBZ
29.0 dBZ
25.0 dBZ
20.0 dBZ
15.0 dBZ
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5.0 dBZ
0.0 dBZ
-5.0 dBZ
-10.0 dBZ
Pdf File: cappi_100km.cappi
Clutter Filter: DFT 6
Time sampling: Variable
PRF: Variable
Range: 100 km
Resolution: 0.400 km/pixel
Height: 2.000 km
Alg type: PCAPPI
CAPPI Range: 2 km to 104 km
Data: Radar Data
Rainbow® Selex ES GmbH
50 km
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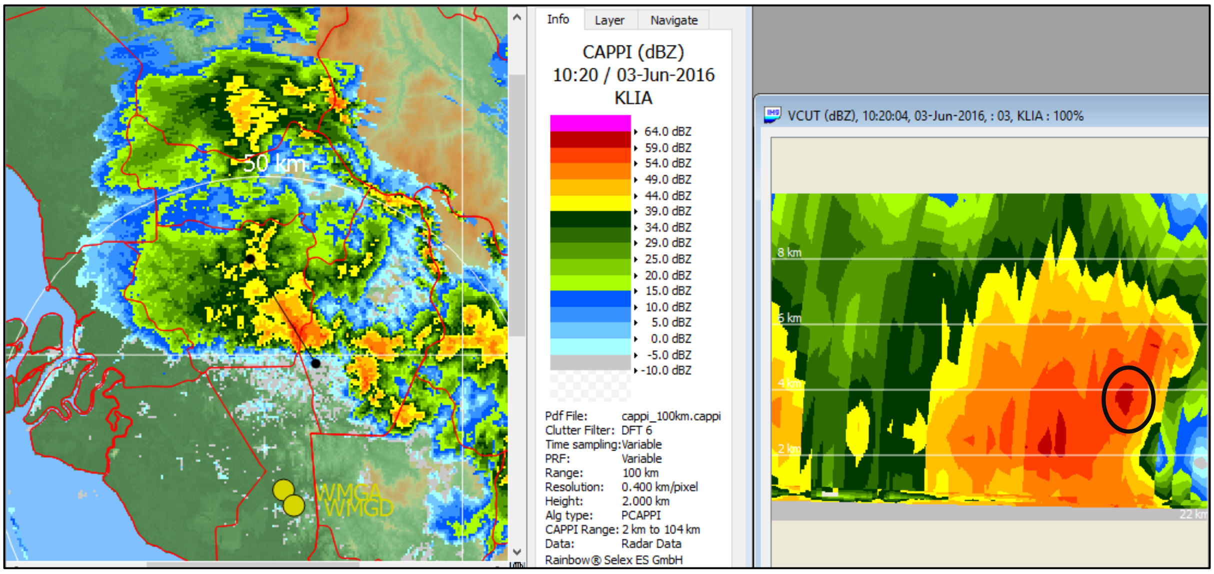
WMGD
VCUT (dBZ), 10:15:04, 03-Jun-2016, KLIA : 100%
8 km
6 km
4 km
2 km
32 km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KLIA
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25.0 dBZ
20.0 dBZ
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-10.0 dBZ
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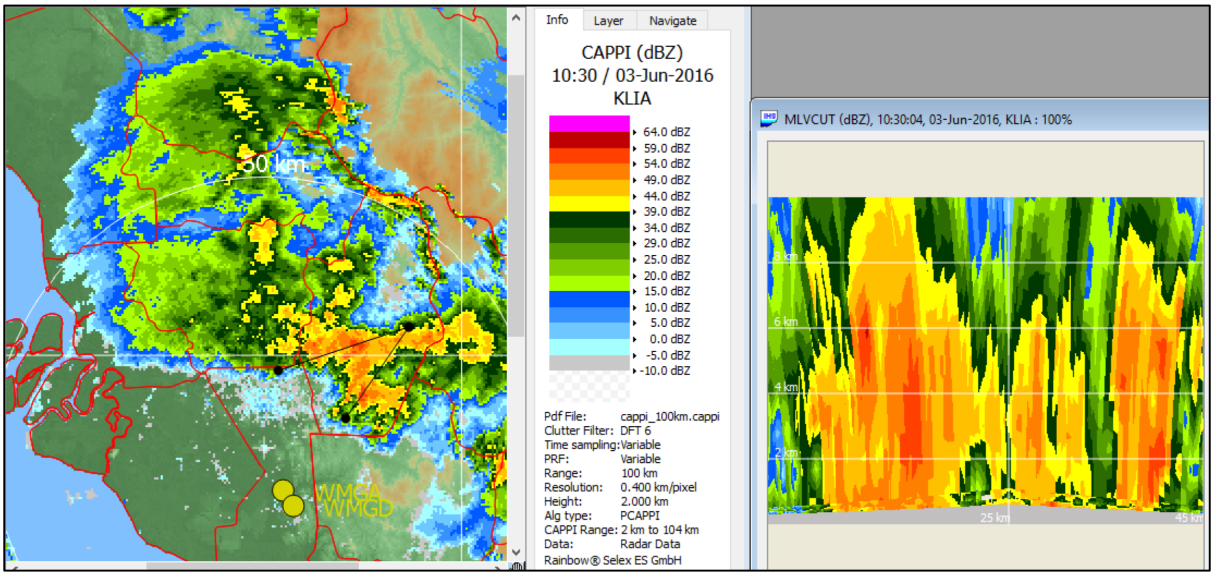
Clutter Filter: DFT 6
Time sampling: Variable
PRF: Variable
Range: 100 km
Resolution: 0.400 km/pixel
Height: 2.000 km
Alg type: PCAPPI
CAPPI Range: 2 km to 104 km
Data: Radar Data
Rainbow® Selex ES GmbH
50 km
WMGA
WMGD
VCUT (dBZ), 10:20:04, 03-Jun-2016, : 03, KLIA : 100%
8 km
6 km
22 km


Info
Layer
Navigate
CAPPI (dBZ)
10:30 / 03-Jun-2016
KLIA
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54.0 dBZ
49.0 dBZ
44.0 dBZ
39.0 dBZ
34.0 dBZ
29.0 dBZ
25.0 dBZ
20.0 dBZ
15.0 dBZ
10.0 dBZ
5.0 dBZ
0.0 dBZ
-5.0 dBZ
-10.0 dBZ
Pdf File: cappi_100km.cappi
Clutter Filter: DFT 6
Time sampling: Variable
PRF: Variable
Range: 100 km
Resolution: 0.400 km/pixel
Height: 2.000 km
Alg type: PCAPPI
CAPPI Range: 2 km to 104 km
Data: Radar Data
Rainbow® Selex ES GmbH
50 km
WMGA
WMGD
MLVCUT (dBZ), 10:30:04, 03-Jun-2016, KLIA : 100%
6 km
4 km
2 km
25 km
45 km

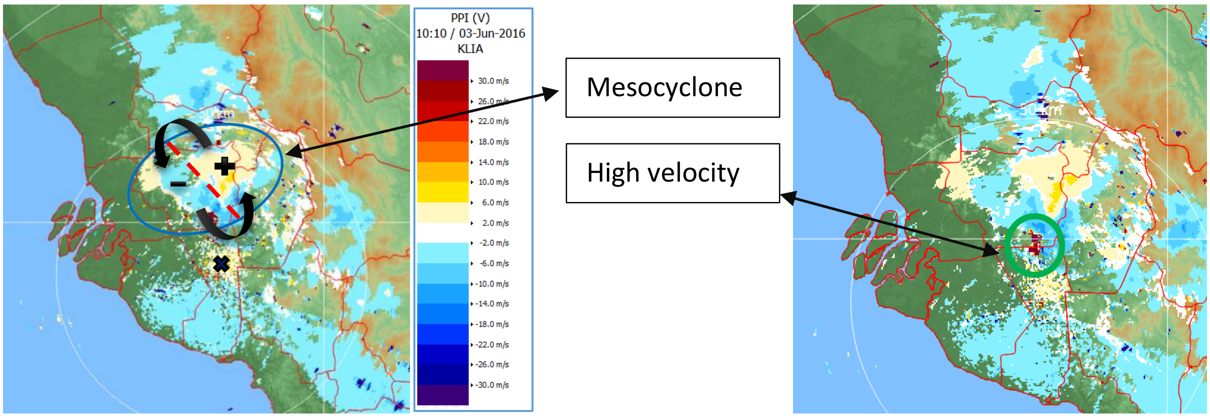

Figure 25: The cross-section of rain echoes view to detect the maximum reflectivity and velocity products provide mesocyclone signatures.

Figure 26: The occurrence of severe storm that produce large hails in Bukit Jalil areas (Courtesy: Astro Awani)

Maximum reflectivity values for this event is in range of 64 dBZ, hence hails is suspected occurred during this time. Looking at the ZDR values as shown in Figure 27, it indicates 3.0-5.0 dB referred to giant rain drops with ice cones. Meanwhile, using KDP values which is estimated about 3.0-4.0 deg/km, resulting in possibility mixed with and coating hail. Therefore, using these dual polarization products, we can conclude that the possible of either melting hail or substantial amount of liquid water falling with the possible hail in this areas. The hail occurrence can be identified with additional information of dual polarization products as shown in Figure 28. In comparison with radiosonde data, the freezing level from 0000UTC observation shows that the height is 4.46 km clarify that the peak reflectivity upper than freezing level height yield the occurrence of hails.

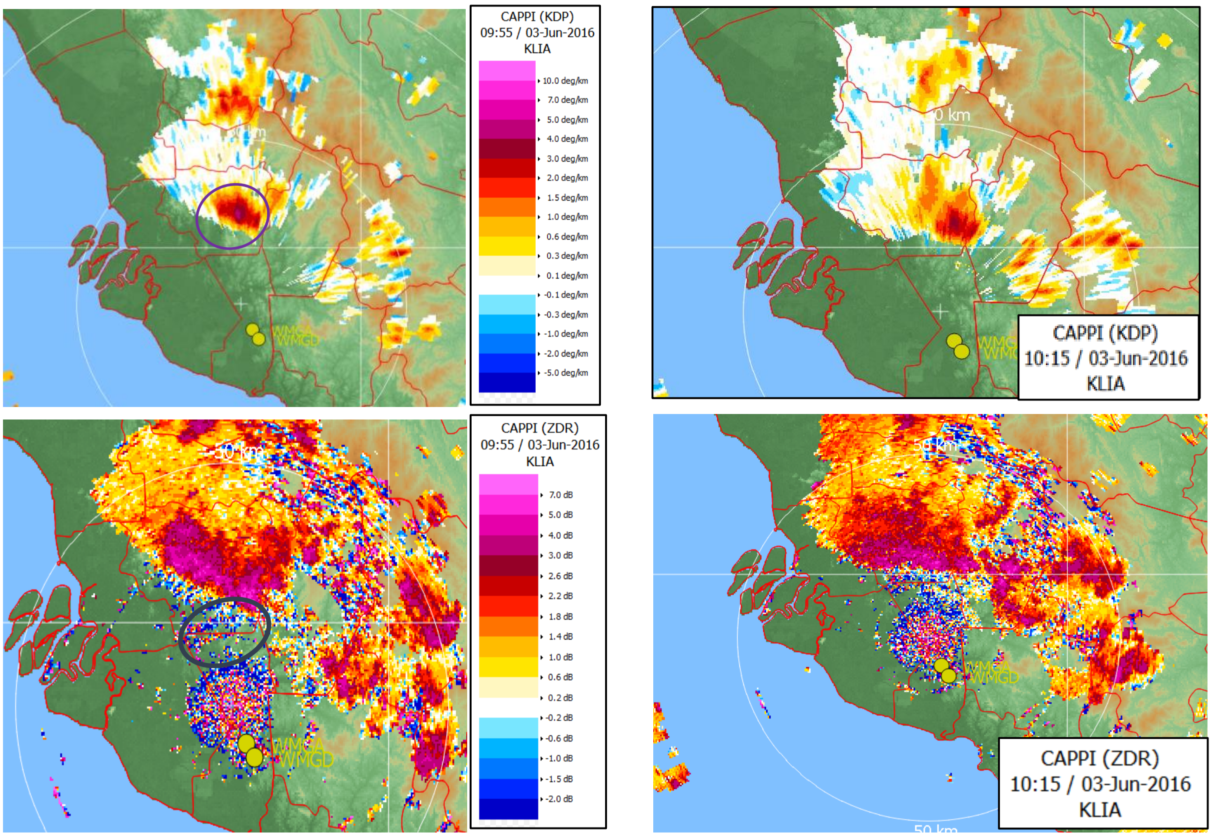

Figure 27: The dual polarization products to identify hails

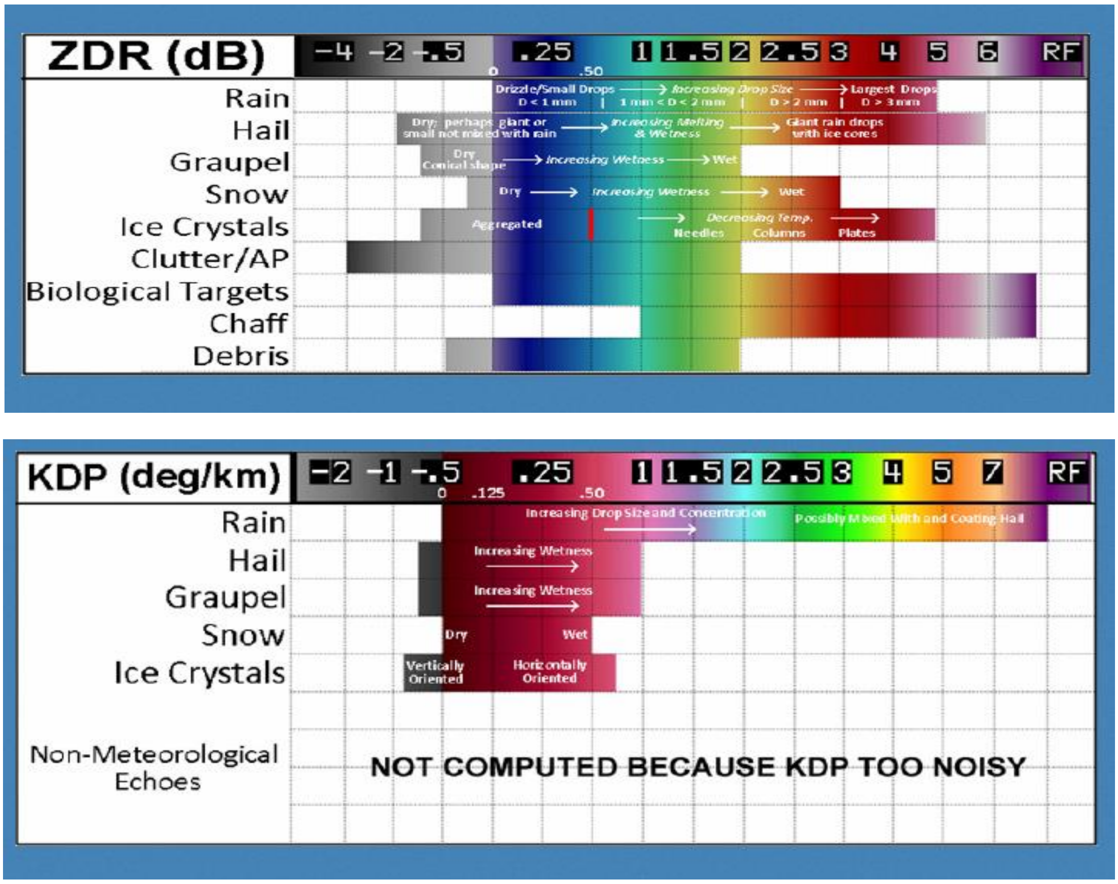

Figure 28: The table of dual polarization products of KDP and ZDR (Courtesy:NOAA)

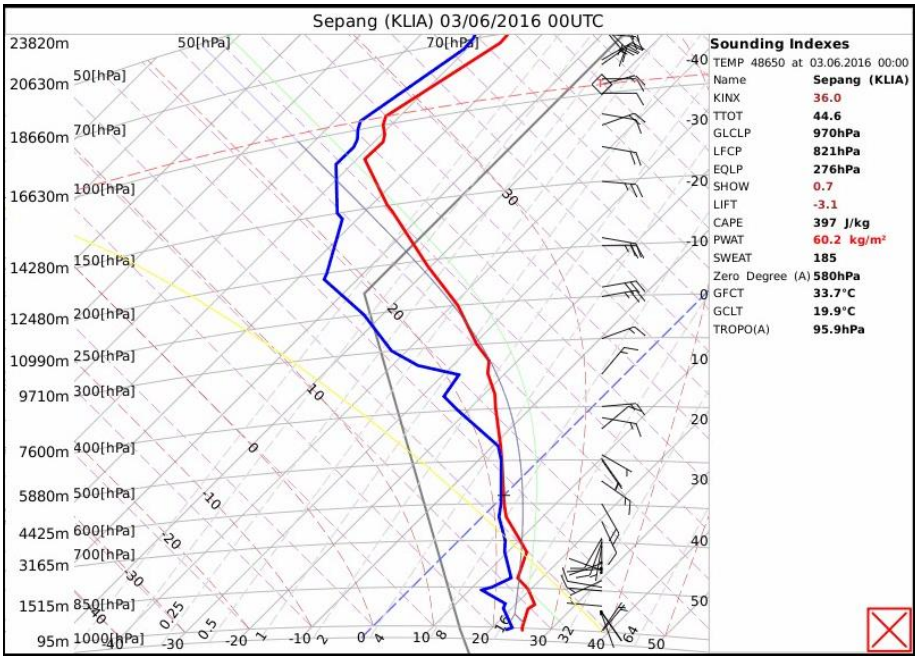

Figure 29: The radiosonde data with the freezing level at 580 hPa (4462.5 m)

Table 4: Summary of landspout events using velocity and reflectivity products

Velocity Products				
Time Occurrence	Event A	Event B	Event C	Event D
Before	No signature	No signature	No signature	No signature
Current	Anticyclonic	Cyclonic	Divergence	No signature
After	Anticyclonic	Convergence	Anticyclonic	No signature
Reflectivity Products				
Time Occurrence	Event A	Event B	Event C	Event D
Period of reflectivity more than 55 dBZ	-	10 minutes	-	-
Maximum reflectivity	54 dBZ	56 dBZ	51 dBZ	48.5 dBZ
Height from AGL at point of maximum	5 km	4 km	5 km	3 km
Echo Tops	10 km	10 km	10 km	14 km
Radiosonde data at 0000Z for freezing level 0˚C	4.69 km	4.74 km	4.78 km	4.86 km

*AGL=above ground level

Referred to Table 4, landspout features are hard to define from the both of velocity and reflectivity radar products since there are no well-found signature from the radar products. Moreover, landspout cannot be detected by the weather radar as its characteristics for the tornadoes signature not exist. Landspout is another type of non-supercell tornado which is similar to waterspouts, that is usually visible and have a narrow, rope-like condensation funnel extending from cloud base to the ground. These landspout is typically short-lived, weak and exist before precipitation is detected on radar. It is hard to detect either from the reflectivity products or velocity products. Nonetheless, anticyclonic and cyclonic signature can may assist the forecasters that rotation of landspout occurred at the events areas. Furthermore, Japan Meteorology Agency (JMA) had discussed about the occurrence of tornado in Malaysia and it can be detected using Numerical Weather Prediction (NWP) Potential Indices that developed by them. The example of this 24 hours forecast model and its model output for Malaysia's tornado are described in Figure 30.

Index	Acronym	Unit	Meaning	Remarks
Convective Available Potential Energy	CAPE	J/kg	Atmospheric instability	
Storm Relative Environmental Helicity	SREH	m^2s^{-2}	Vertical wind shear	
Energy Helicity Index	EHI	none	Tornado forecast parameter	
Tornado Velocity Parameter	TVP	m/s or Fujita-scale	Estimated wind speed of tornado	developed in JMA
Downdraft CAPE	DCAPE	J/kg	Downdraft energy	

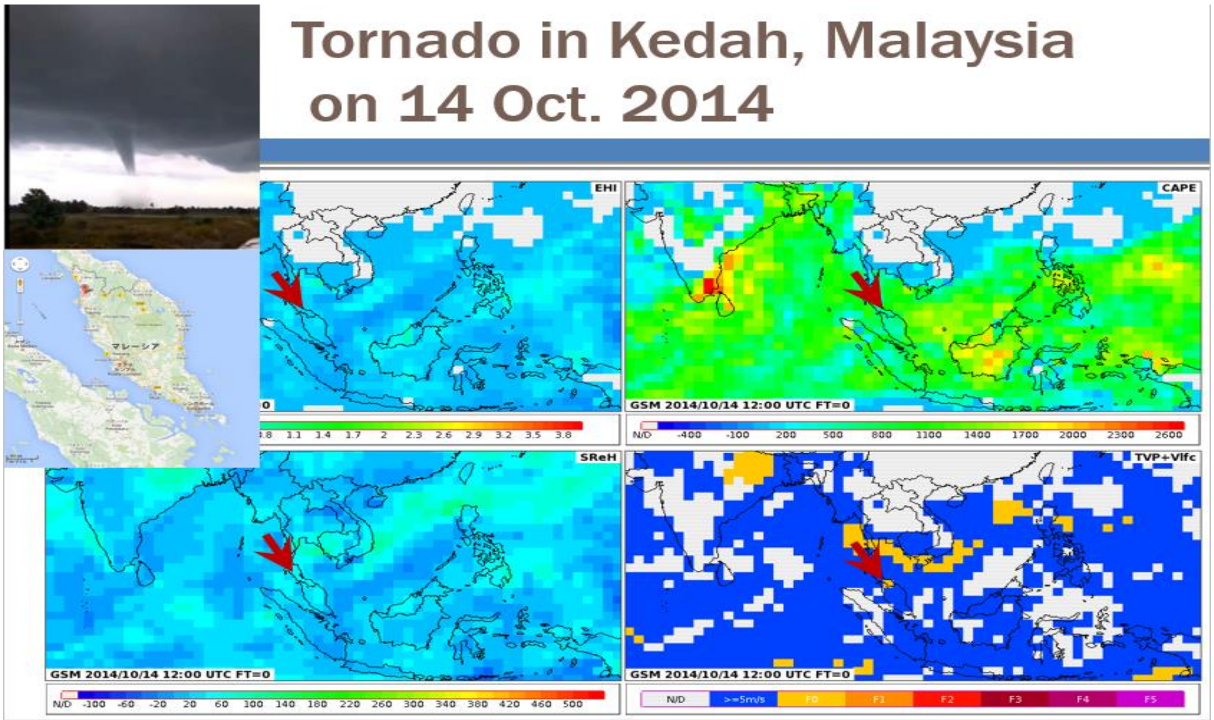

Figure 30: The model of NWP Potential indices and forecast for tornado occurrence in Malaysia on the 14th October 2014. (Courtesy:JMA)

Table 5: Summary of hail events using reflectivity products

Reflectivity Products for hail phenomenon			
Time Occurrence	Event A	Event B	Event C
Period of reflectivity more than 55 dBZ	30 minutes	30 minutes	50 minutes
Maximum reflectivity	59.5 dBZ	56 dBZ	64 dBZ
Height from AGL at point of maximum	6.2 km	5.7 km	6.1 km
Echo Tops	18 km	20-25 km	15 km
Radiosonde data at 0000Z for freezing level 0˚C	4.72 km	4.62 km	4.46 km

Typically, hail occurrence is developed in the mesocyclone environment that can produce severe thunderstorm with gusting wind. In discussion of (Holleman, 2001) stated that the suggestion by Mason (1971) to use the threshold of reflectivity in CAPPI-method for differentiating of hail and severe rain with the value 55 dBZ. As indicated in Table 1 from the reference of NWS NEXRAD reflectivity level, the possibility of small hail can be occurred. Even though in landspout phenomenon indicates 56 dBZ, there was no report of hail at Pandamaran areas compared to hail occurrence at Bandar Tun Razak, Jengka by referring at Table 4 and 5 respectively due to the maximum reflectivity value is located at the height of 4 km rather than the freezing level values is 4.74 km. Data in Table 5 shown that the reflectivity values above 55 dBZ with the combination of top of cloud higher than 15 km and the height of location for maximum reflectivity should be greater from freezing level values. The maximum reflectivity can be greater than 60 dBZ which produce large size of hail that happened in Bukit Jalil area showed that the freezing level values can be dropped below than 4.5 km.

4. Conclusions

The main objective for this analysis is to expose the forecaster the importance in analysing of radar echoes to gain radar knowledge of detection hail and landspout phenomenon. From this study, the landspout existence is hard to define using both reflectivity and velocity radar products. As discussed in section before, landspout can be occurred before the precipitation falling down at the areas. In addition, the limitation for the analysis is due to the temporal resolution for Doppler mean radial velocity product is only 30 minutes that effect the severe weather observation which the possibility of landspouts' features in this interval can be detected. In addition, the life cycle of landspout is short and it perhaps ended in the interval of 30 minutes. Therefore, the Doppler radial velocity should be observed every 5-10 minutes to detect landspout presence with the further data of analysis. JMA in their development produce NWP Potential Indices which is successfully detected the landspout events should be learnt by the forecasters.

In the meantime, hails will happen in the mesocyclone signatures of velocity products and can be observed by using the vertical cross-section of reflectivity products. The forecasters are needed to use whether IRIS or RAINBOW software to investigate in details of two-dimensional view of cloud features using radar products. Applying CAPPI and Doppler Volume Scan can provide in details the cloud structures of maximum reflectivity, echo tops and the height of maximum reflectivity. The analysis reveals that the freezing level values from radiosonde data and the height of top cloud play the main role in hail existence. In conjunction with the presence of reflectivity values above 55 dBZ with the combination of top of cloud higher than 15 km and the height of location for maximum reflectivity should be greater from freezing level values can produce large hails at the areas. It is recommended to study further analysis of hail phenomenon to provide the criteria of hails in Malaysia which the severe hail index can be determined in this country.

Henceforth, the forecasters should analyse the radar echoes and identify the severe weather phenomenon to provide early warnings with additional observation tools such as satellite images, tephigram and observation data together with Numerical Weather Products (NWP) models. This study can contribute the knowledge of hails and landspout occurrence to forecasters the importance of analysing of radar products in term of reflectivity and velocity products. In the meantime, there are many radar products can be studied in details related to severe weather phenomenon and it is recommended to analysis in details for the next research. Dual polarization products also provide the necessary information to differentiate the type of hydrometeors that will be discussed more in the severe weather phenomenon analysis.

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