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Comparison of CAPPI Height 2 km and 1 km during Northeast Monsoon

By
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Abstract

Constant Altitude Plan Position Indicator (CAPPI) is one of the radar product that used for the analysis and observed tools by forecasters. The determination of CAPPI height is varied in each country which the altitude between 1 until 3 km. It is depended on the purpose of data use and radar operational. CAPPI height is determined by the factor of topography and the minimization of radar reflectivity error, bright band and so on. The radar stations namely Kuantan, Kota Bahru, Kluang, Kota Kinabalu and Kuching radar stations are chosen for the study during the period of Northeast monsoon. Analysis of radar images by comparing 1 km and 2 km CAPPI height is utilized to find the difference of intensity and precipitation areas. The cross-section tool from IRIS software is used to identify the height for high intensity of rain clouds development. The results showed that during Northeast monsoon, all rain clouds developed below than 2 km above ground level can be captured by 2 km CAPPI height. In addition, most of developing rain cloud located between 2 until 4 km heights which CAPPI 2 km able to capture the high intensity rather than 1 km. When consuming 1 km CAPPI, most of the radar echoes revealed less intensity because the radar beam at multiple angles cannot detect the intense rain clouds which mostly located until 5 km above ground level. Ground clutter echoes appeared more at CAPPI 1 km height which it might be confused to the forecaster when interpreting the radar images. In conclusion, CAPPI 2 km is able to capture more intensity of rain echoes and less ground clutter seem in the radar images.

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1.0 Introduction

Weather radar is a remote sensing tool that can observe target of hydrometeor such as rain, hail, snow and others. Typically, the range of radar observation is 150-300 km which beyond on that, radar cannot detect due to the curvature of earth. When making observation, the radar antenna is set at a given certain elevation angle and then rotated at a full of 360 degrees. Weather radar in Malaysian Meteorological Department (MMD) scanning strategies is divided into two task namely Long-Range and Doppler. The product for Long-Range is reflectivity and rainfall rate which the high range is 300 km as displayed in Figure 1. Meanwhile, Doppler scanning strategies have 15 elevation angles as illustrated in Figure 2 which is divided into Doppler A, B and C that produce display data of velocity, reflectivity and spectrum width. Furthermore, the volume scan is the data of elevation angles are grouped together as example Volume Scan Doppler A is consisted of elevation angle 0.0, 0.7, 1.5 and 2.5 degree.

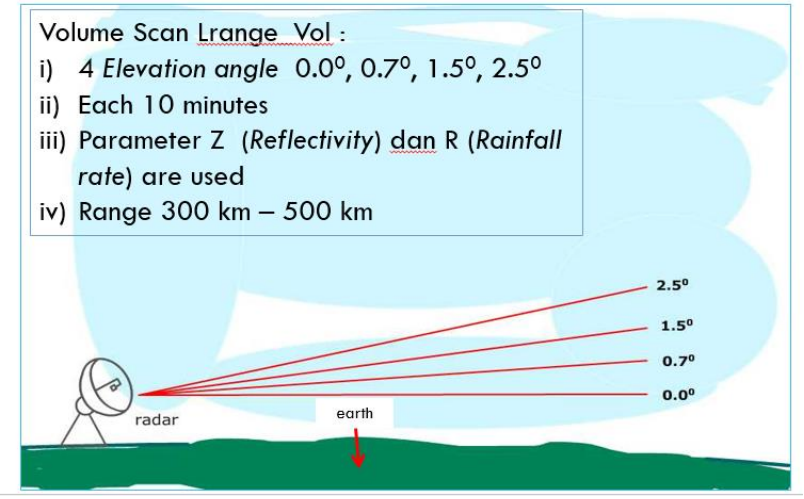


Figure 1: Scanning strategies implement in MMD's weather radar network for Long-range Task

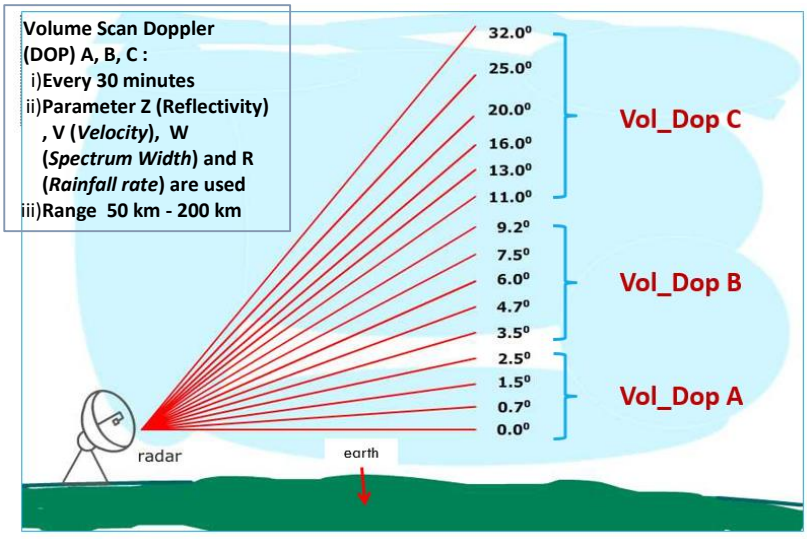


Figure 2: Scanning strategies implement in MMD's weather radar network for Doppler Task

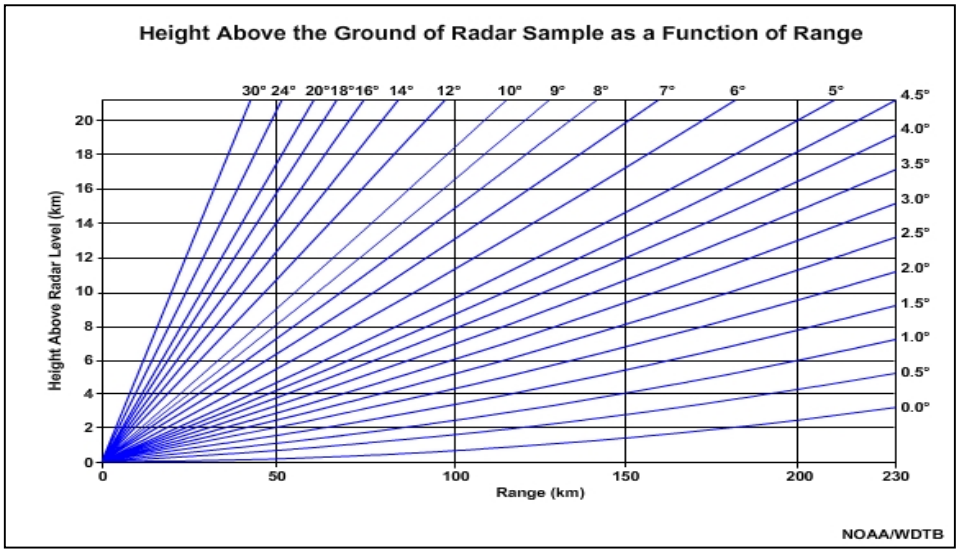


Figure 3: The height of radar beam depends on the radar distance for elevation angle

Radar data visualization generally can be displayed into **P**lan **P**osition **I**ndicator (PPI). The PPI data is a radar measurement from a single rotation of the antenna at a certain elevation angle. It is equivalent to display data at along one of the blue line of the above graph (Figure 3).

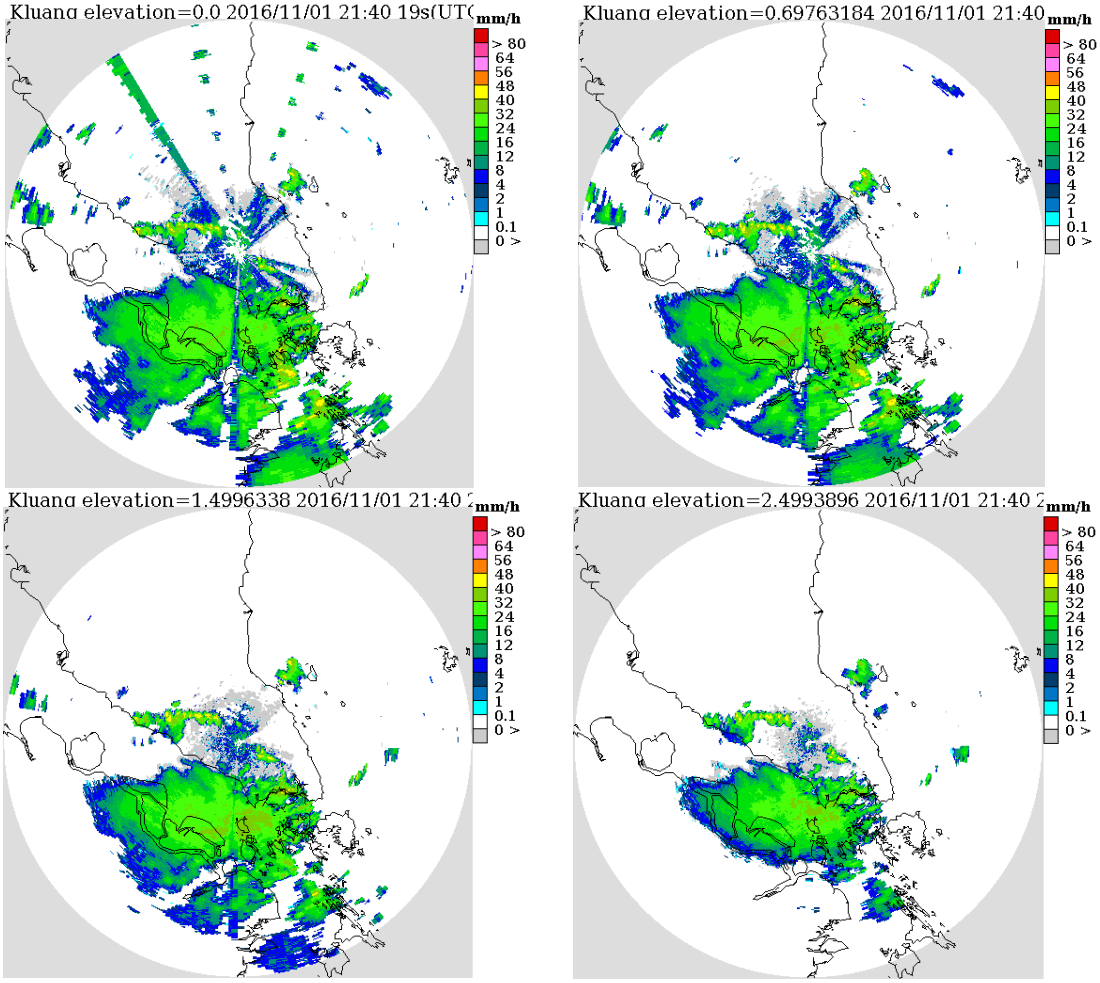


Figure 4: The PPI images for certain elevation angles

Figure 4 shows the illustration of rainfall images product at elevation angle 0.0, 0.7, 1.5 and 2.5 degrees. As the altitude of radar measurement increase with range, the interpretation of PPIs may sometime be difficult since the radar beam gets higher in the atmosphere with distance from the radar. For example, on the same observation images, elevation 0.0 degree will often observe rain at far range and low levels, meanwhile elevation 2.5 degree will observe rain at close range and high levels.

In comparison, CAPPI data are a cumulative of multiple PPIs at a given altitude above ground to produce a 2D map of radar measurement. As illustrated in the images as displayed in Figure 5, a CAPPI can be produced by utilizing the data of the PPIs (blue line) that intersect with the thick red line. A low elevation angle like 0.0 degree and 0.5 degree at 2 km above ground, the radar beam distance is about 190 km and 130 km respectively. Therefore, the volume scan of CAPPI product is vital to sample the low-level precipitation which is most likely to represent the precipitation reaching on the ground.

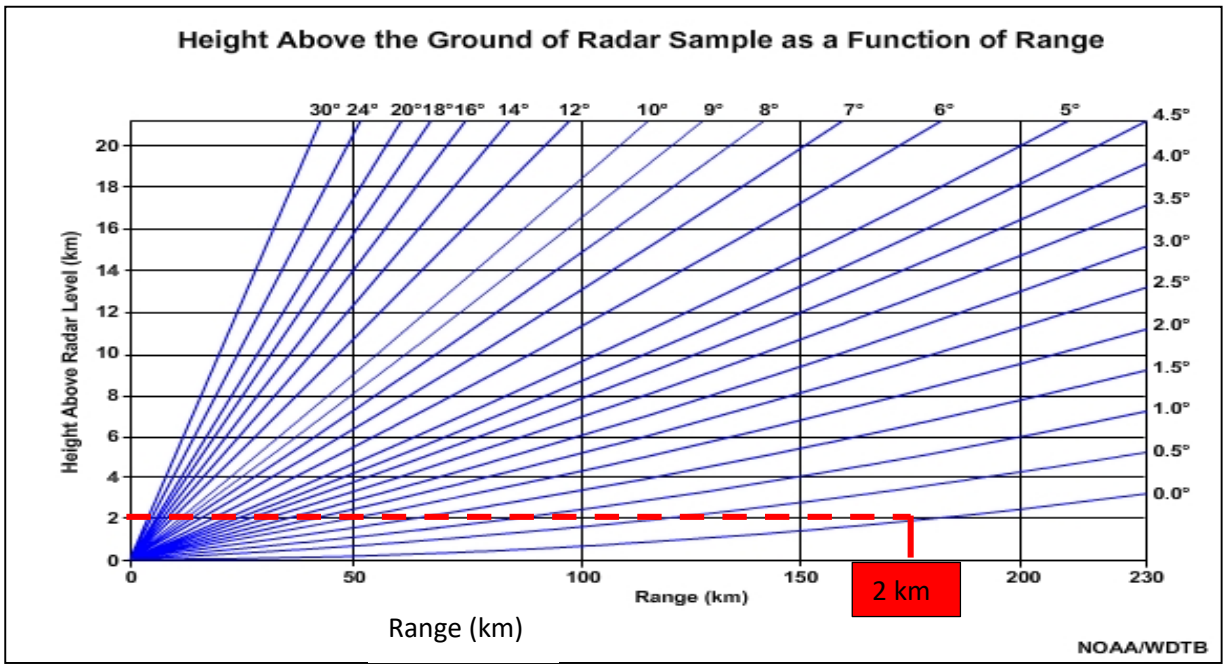
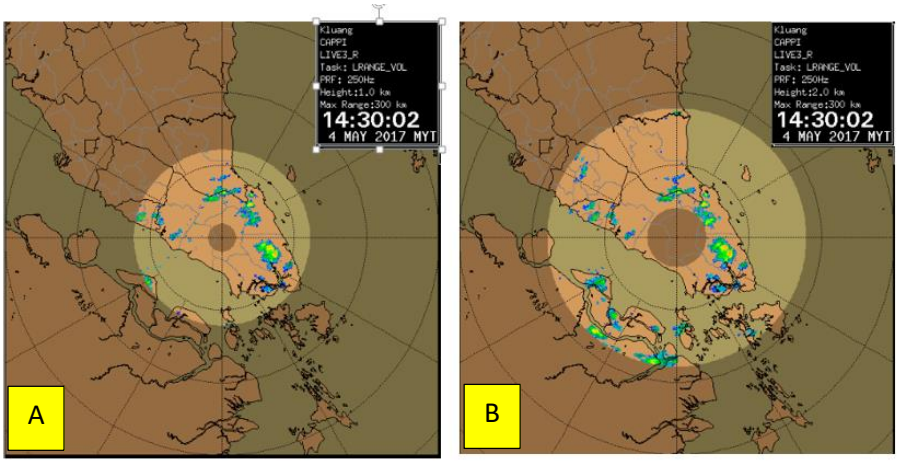
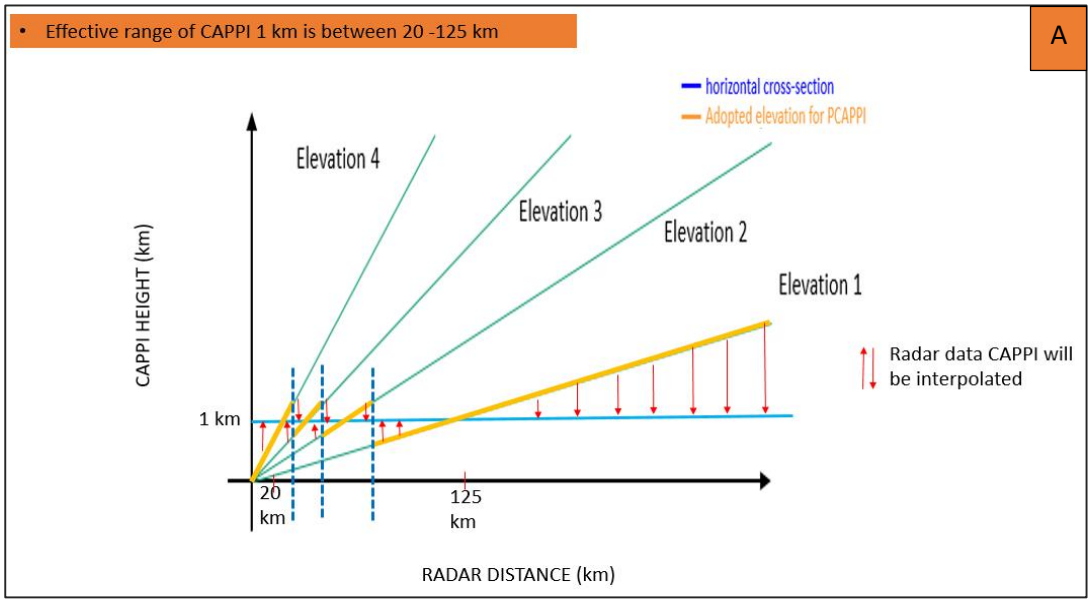


Figure 5: The radar beam distance depend on the elevation angle

CAPPI data is interpolated by using IRIS algorithm which the red arrow indicate that the radar data CAPPI will be interpolated at certain CAPPI altitude. Referring to Figure 6, compared with (A) and (B) with the height of CAPPI 2 km and 1 km respectively in the standard refraction condition for elevation angles as stated in the image, the effective radius of A at CAPPI 2 km is in the range 50-190 km, meanwhile, effective radius for B is about 20-125 km. The greater CAPPI height produce more interpolation data at the nearby radar station, for instance, CAPPI height at 3 km will produce the real data at 70-220 km.





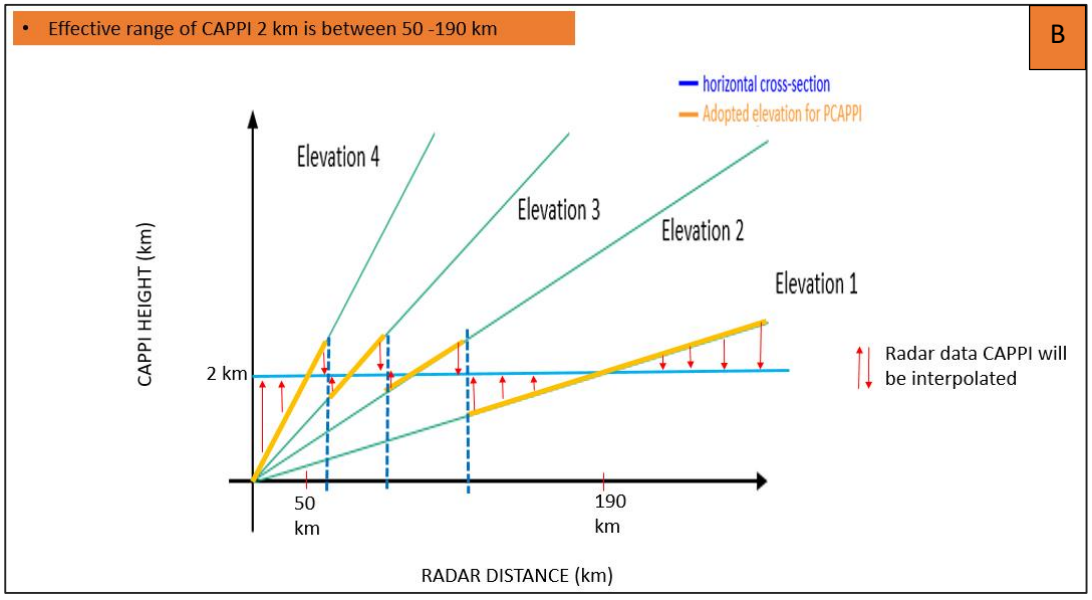


Figure 6: The illustration of CAPPI height at 2 km (A) and 1 km (B) related to distance and data interpolation

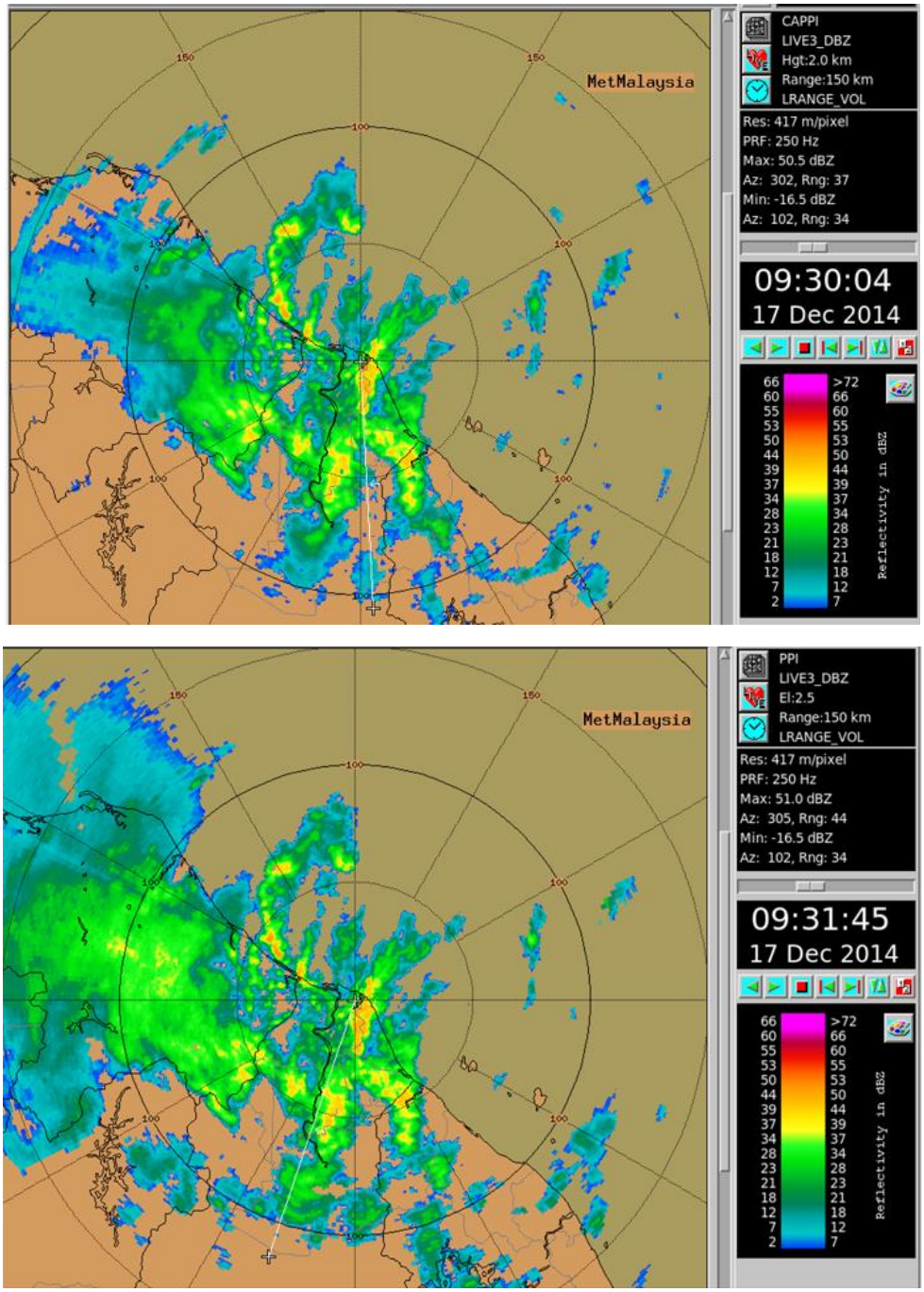


Figure 7: The comparison of CAPPI height 2 km (above) with the PPI image (below) at elevation 2.5 degree

In Figure 7, image display for CAPPI and PPI 2.5 degree is different since CAPPI data is the volume scan at elevation angle 0.0, 0.7, 1.5 and 2.5 degree which the radar data at these certain elevation angle will be combined and interpolated at height of 2 km. In the meantime, PPI 2.5 degree displays real data at one elevation angle only. At certain time, the forecasters are needed to study different PPIs at different elevation angles to know in details the real data of observation images.

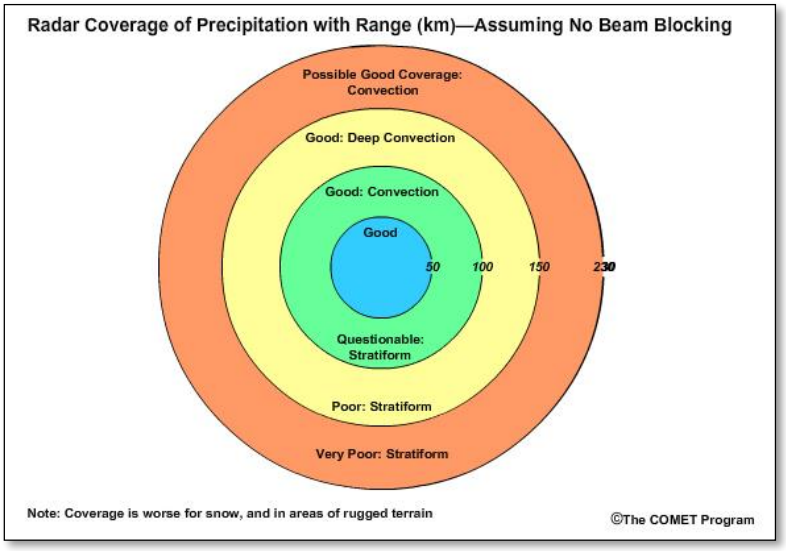


Figure 8: The radar coverage of precipitation with range with assuming no beam blockage (Courtesy: COMET MetEd)

Table 1 is shown for the effective range at certain CAPPI heights. When referring to Figure 8, CAPPI height 2 km and 2.5 km is the best for convection precipitation since the good coverage is in the range until 230 km. Meanwhile, for stratiform precipitation, the best coverage in located until 50 km range. CAPPI height 1.0, 1.5 km and 2.0 km can be selected for the stratiform precipitation with assuming there are no blockage area. The radar coverage for stratiform precipitation is almost poor beyond 100 km from the radar.

Table 1: The effective range of radar coverage for various CAPPI height

CAPPI HEIGHT	Effective Range
1.0 KM	20-125 km
1.5 KM	35-160 km
2.0 KM	50-190 km
2.5 KM	55-220 km
3.0 KM	60-240 km

Basically CAPPI height value is between 1 until 3 km depend on the purpose of data use. The determination of CAPPI height is influenced by topography factor and the developing clouds of precipitation. For instance, Korea Meteorological Administration (KMA) and Japan Meteorology Agency (JMA) use 1.5 km and 2 km CAPPI height respectively. However, Hong Kong Observatory (HKO) uses 3 or 2 km CAPPI height because the movement of storm usually at 3 km height, except in winter, the height could be reduced to 2 km. They mentioned that 1 km is not recommended as it might contain clutter and not storm motion representative (LI, 2012). (Yoo, et al., 2016) mentioned that CAPPI data is not represent the information of rain rate on the ground due to the wind factor. They also stated that since 70% of entire Korean Peninsula covered by mountain which can be referred in Figure 9, 1.5 km of CAPPI height was chosen to secure rather homogeneous data in altitude without blocking significant

terrain. This minimum height also determined to minimize the error in radar reflectivity data due to ground clutter, earth's curvature, bright band and etc.

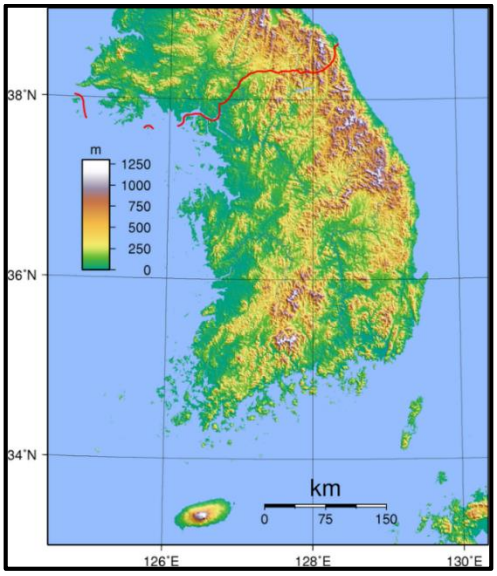


Figure 9: The elevation map of Korean Peninsula

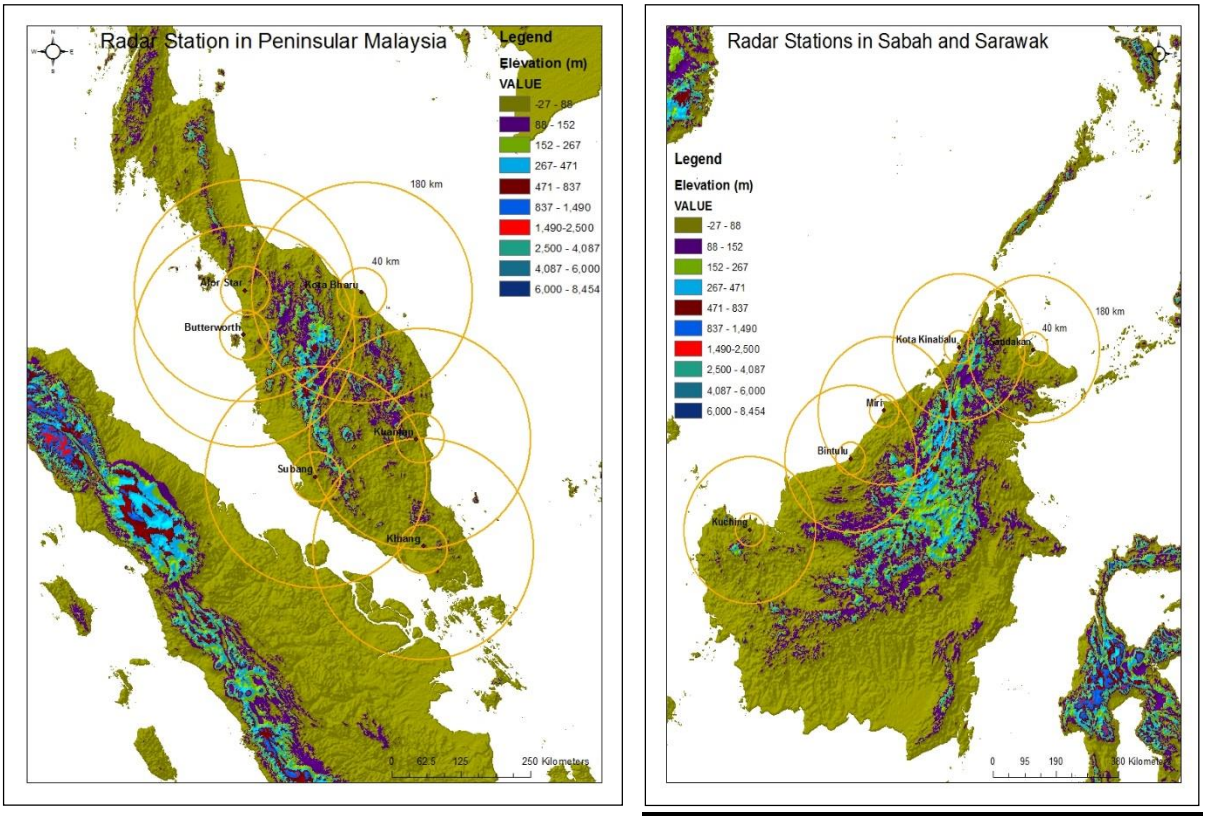


Figure 10: The elevation map of Malaysia

Related to topography data, Malaysia elevation data generally more than 1.5 km as shown in Figure 10, hence the selected CAPPI height at 2 km is reasonable. For instance, at Kuantan radar station which azimuth 310 degree, lowest angle is blocked with topography at 1 km height as described in Figure 11. In fact, the blockage for radar coverage is less at 2 km height.

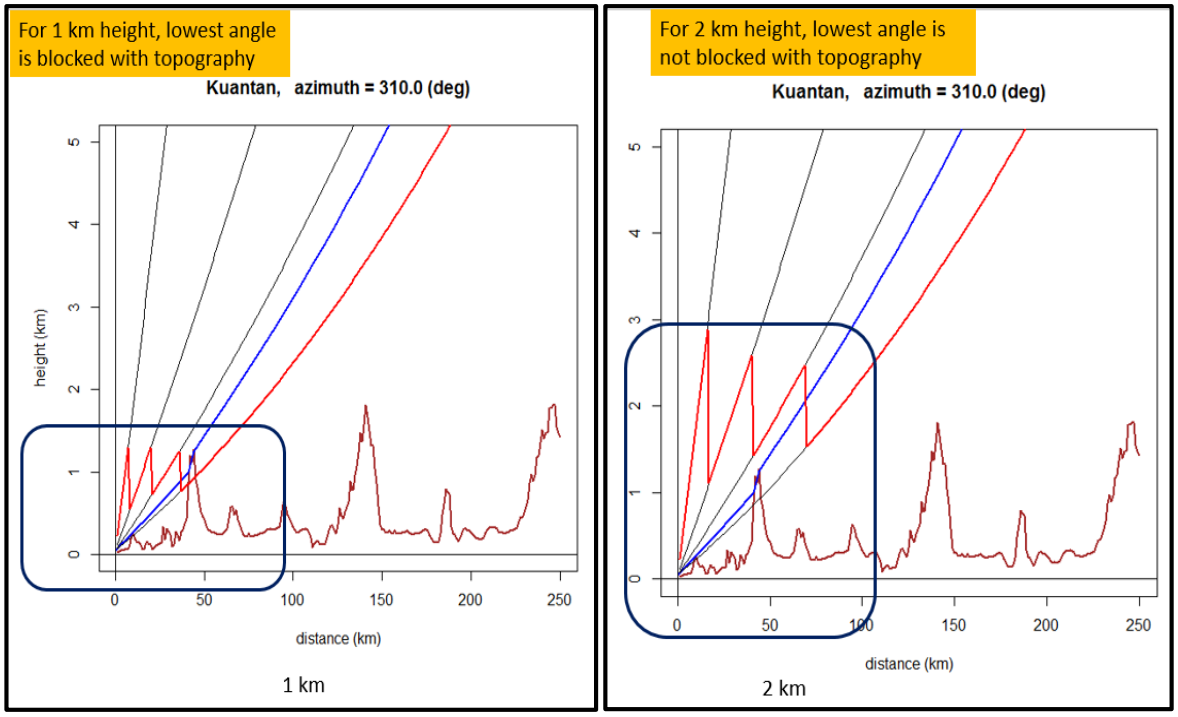


Figure 11: The radar beam range associated with topography data from JMA R-Programming

As discussed by Schumacher in his thesis, the nimbostratus cloud associated with the stratiform rain region typically has base cloud height between 3.5 - 4.5 km and top cloud height at 12 km. In comparison, convective cloud profile had low-level convergence peaking at 2 - 4 km height with divergence above 6 km. The research by Rickenbach and Rutledge also found that the significant of convective rainfall was associated with cells 4 - 10 km in height, concluded that cumulus congestus is an important convective cloud type over the tropical ocean.

In addition, from study by (M.Oue, et al., 2015) on precipitation process using X-band radar, disdrometer and hydrometeor videosonde data near Okinawa Island, stratiform precipitation was characterized by higher number concentration of smaller drops. Meanwhile, convective cell which embedded in a Baiu stratiform precipitation has larger raindrops rather than stratifrom. In this study as illustrated in Figure 12, they found out that between 2 and 4.3 km, the cloud droplets, drizzle and rain are dominated at this level with relative humidity 100%. For the future research, it is recommended to study the microphysics at Malaysia during the northeast monsoon especially between 4 km height above ground level to identify the most dominant particles in cloud development.

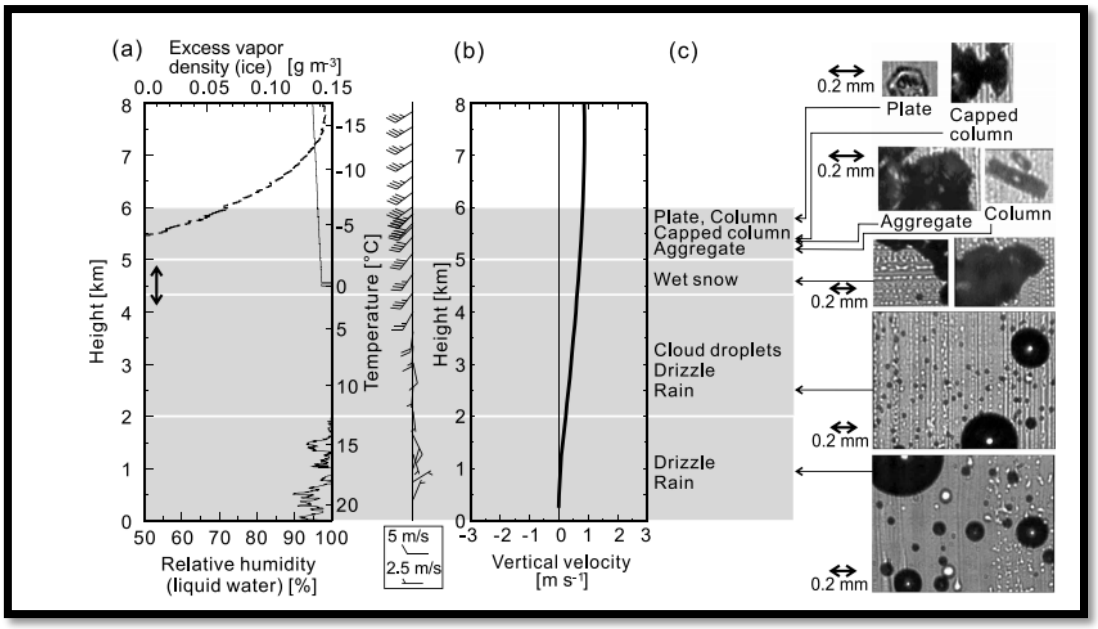


Figure 12: The dominant particles observed by microscope camera (Adapted from: (M.Oue, et al., 2015)

2.0 Data and Methodology

For the analysis of CAPPI height comparison, several rainfall events were selected during Northeast Monsoon by using weather radar stations as illustrated in Table 2 from case study (1) until (6). Meanwhile, case study (7) was selected to analyse the effect of CAPPI height 1 km related to topography data.

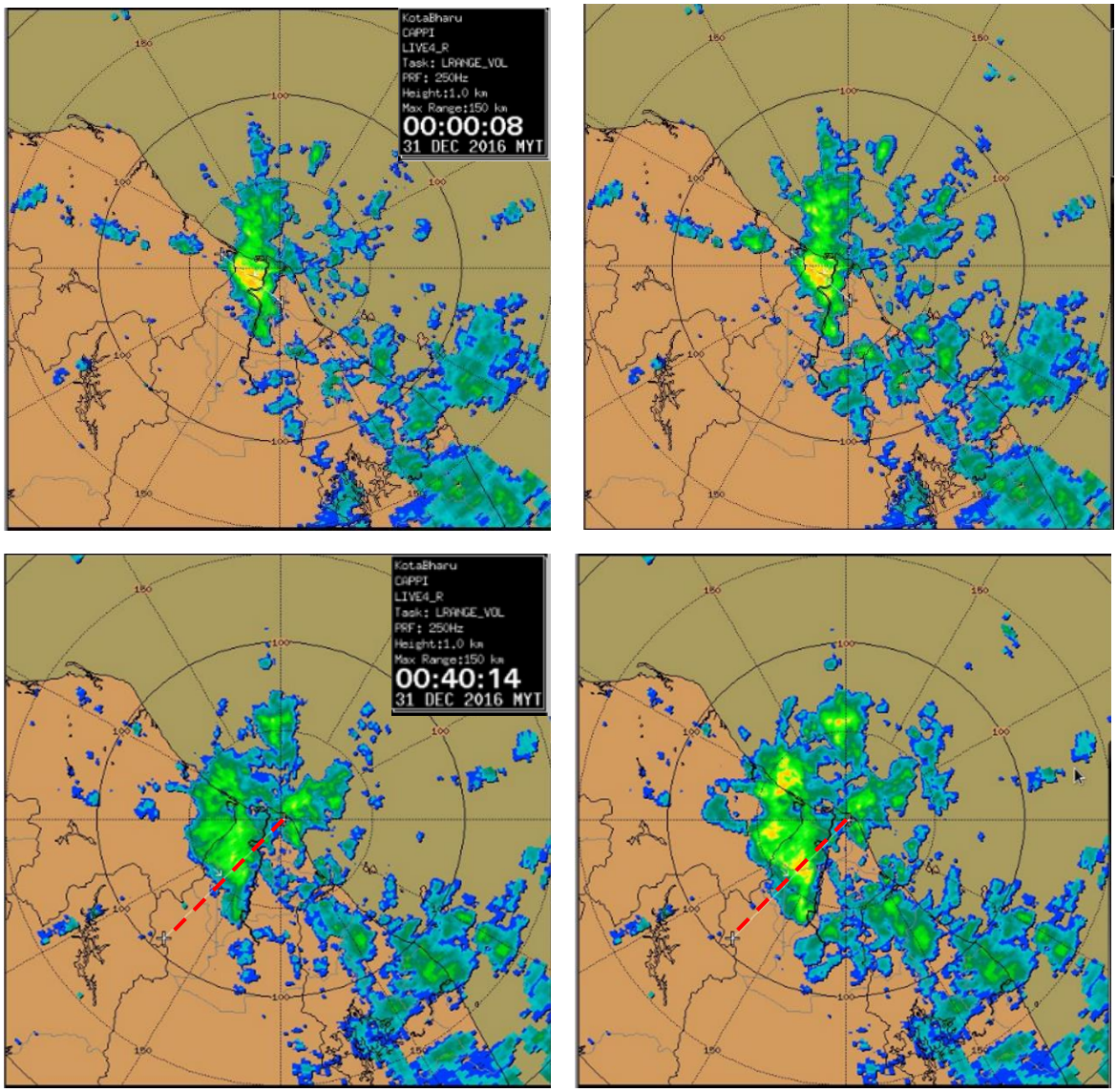
Table 2: The selected date and radar stations of case study

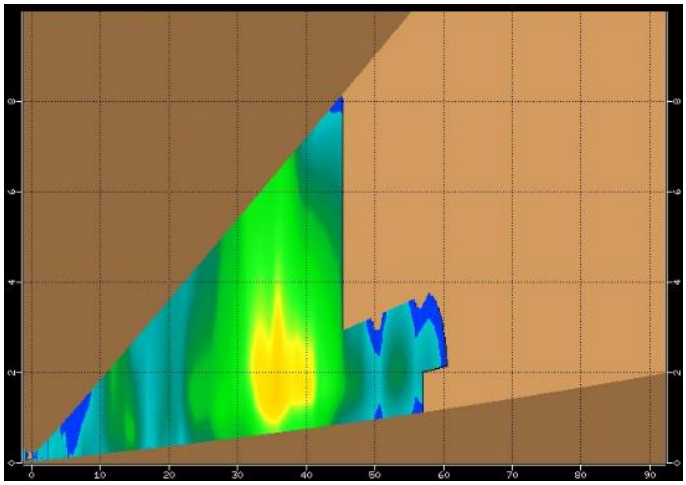
Case Study	Radar	Date
1)	Kota Bahru	31 Dec 2016
2)	Kota Bahru	25-27 Jan 2017
3)	Kuantan	24 Jan 2017
4)	Kluang	25 Dec 2016
5)	Kuching	31 Dec 2016
6)	Kota Kinabalu	1 Jan 2017
7)	Kluang	9 Feb 2017

Cross-section tools is essential to analysis a storm's structure and identify the height of rain cloud. 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. This method is used to identify the height of cloud and the maximum reflectivity or rain rate that produce the maximum interpretation on the radar images. The maximum indicator will be dissimilar on the CAPPI images depend on the CAPPI height determination. In addition, JMA Radar Beam Range software is used to analyse the effect of topography data at different height of CAPPI. Elevation angle composite table map is created to find the blockage and the performance of radar coverage for each elevation angle.

3.0 Results and Discussion

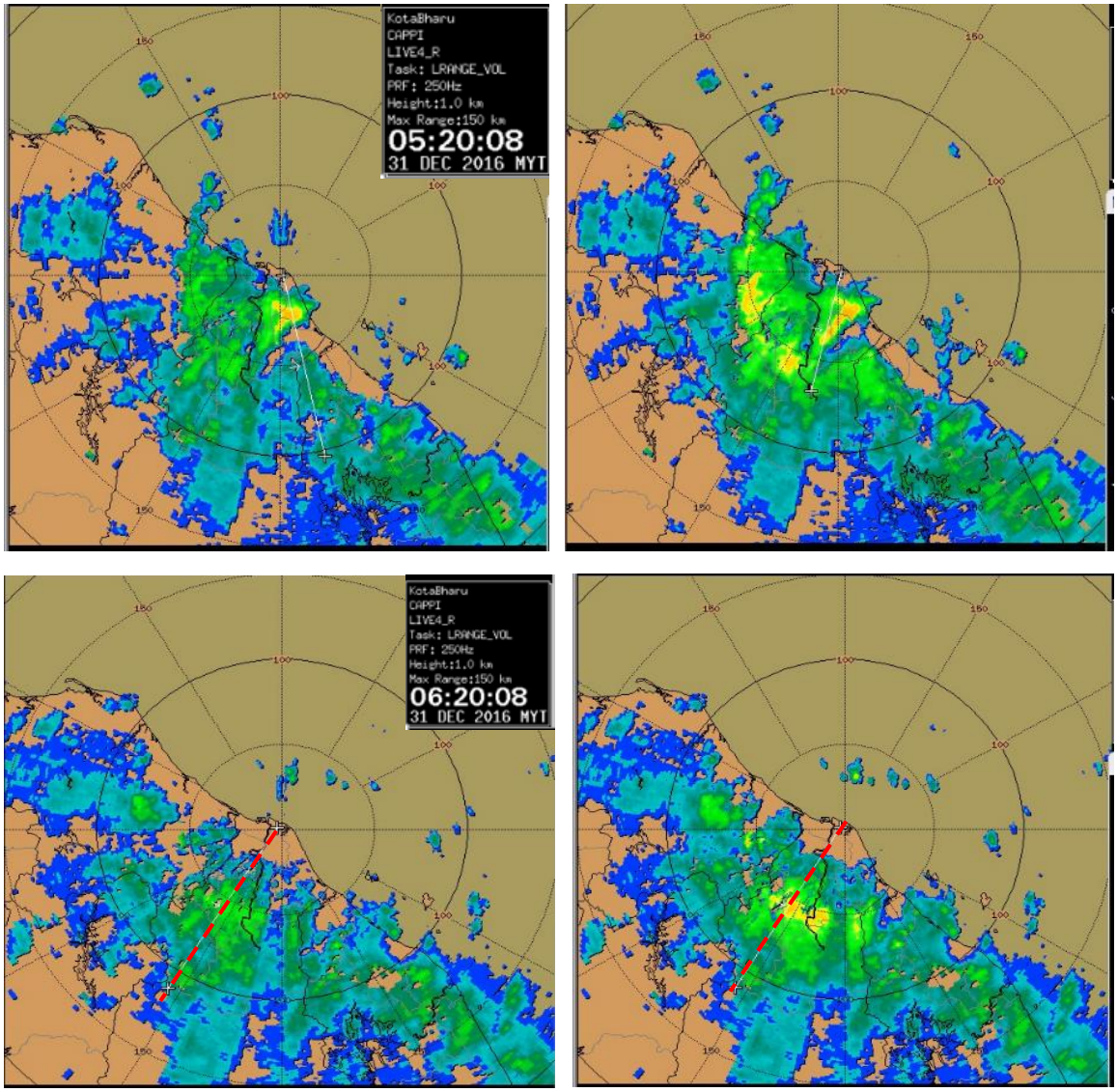
a) Case Study 1: Kota Bahru Radar Station on the 31st Dec 2016[1]

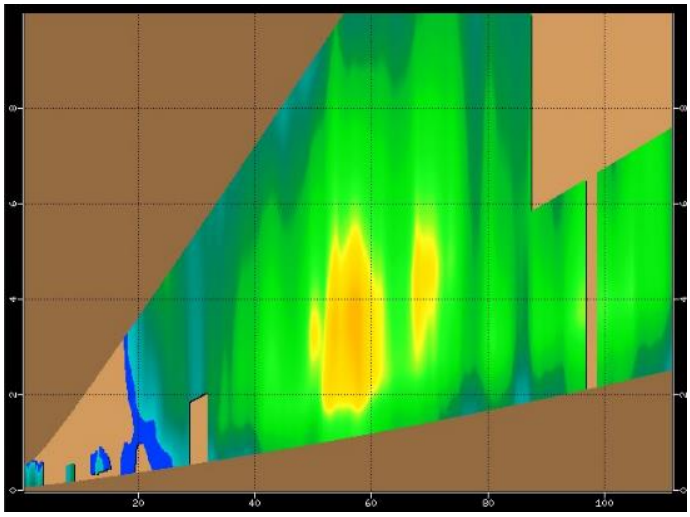




Cross section at red dashed line show that the height of highest intensity (yellow indicator) located between 1.5 km – 4 km. CAPPI 1 km height showed less intensity than CAPPI 2 km height.

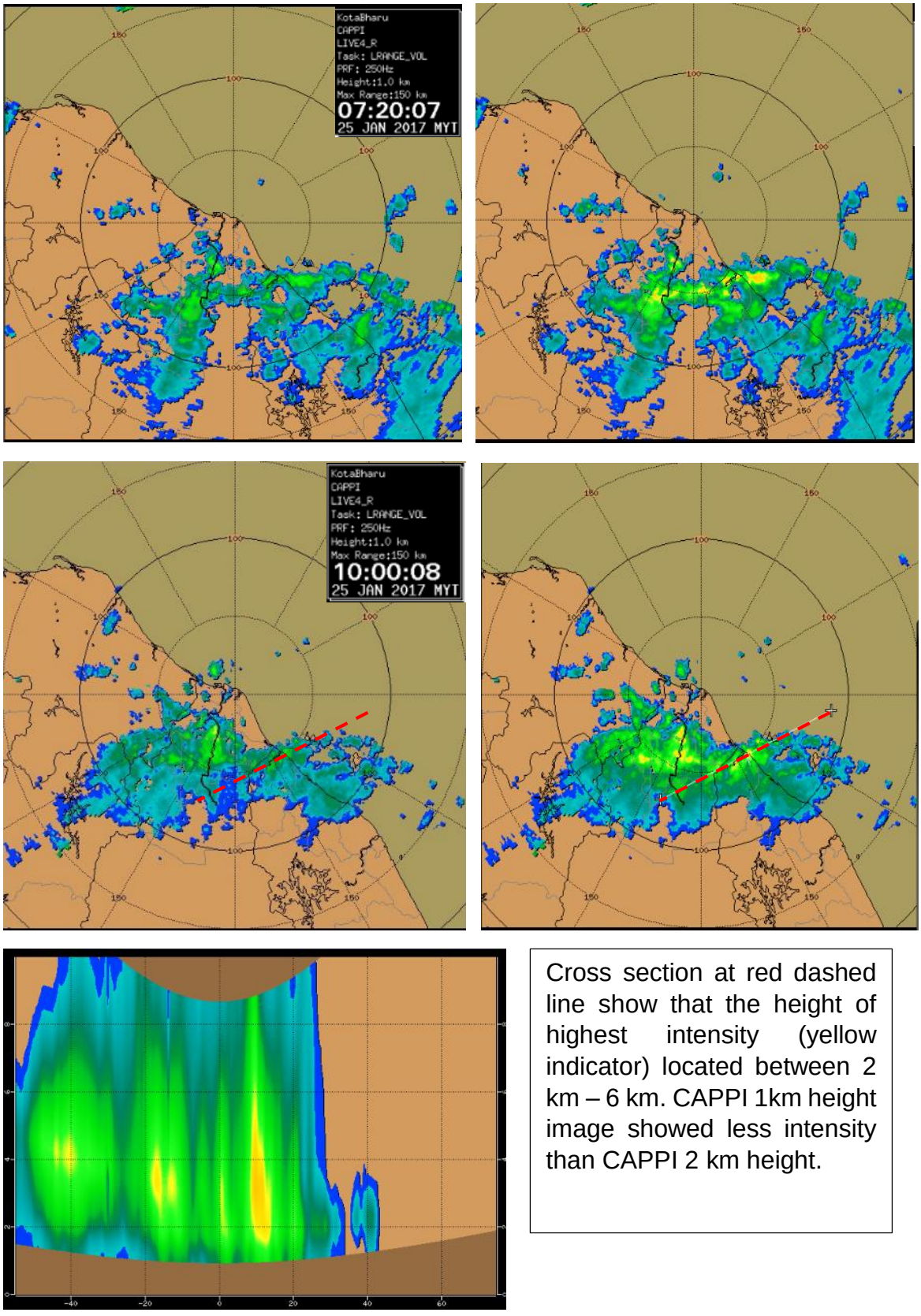
[1] Left images indicate CAPPI 1km, right images indicate CAPPI 2 km





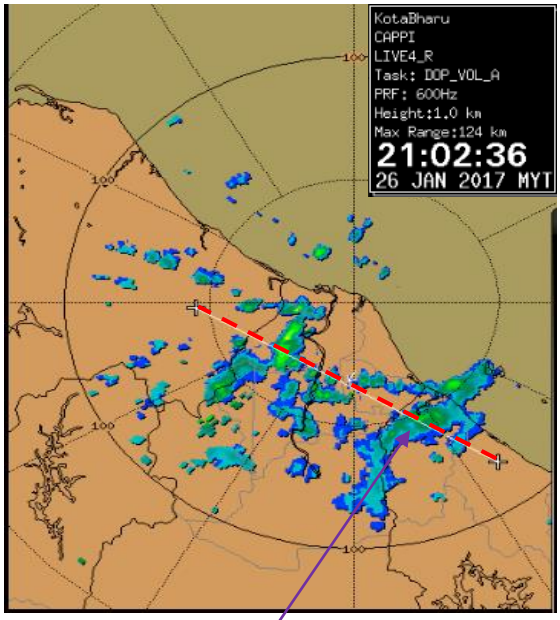
Cross section at red dashed line show that the height of highest intensity (yellow indicator) located between 2 km – 6 km. CAPPI 1km height image showed less intensity than CAPPI 2 km height.

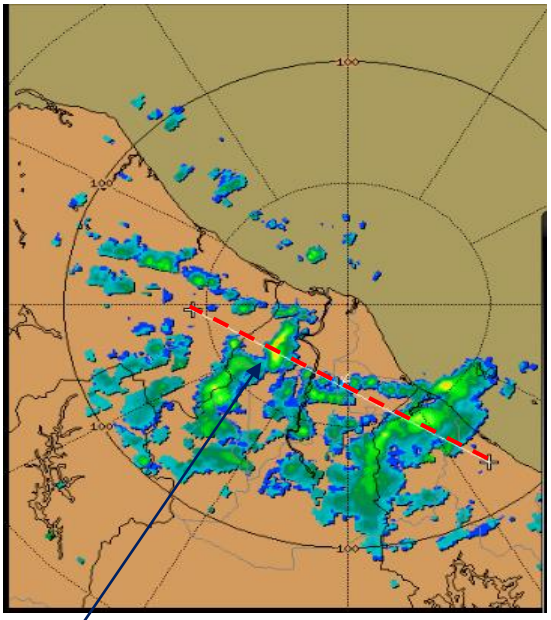
b) Case Study 2: Kota Bahru Radar Station on the 25th -27th Jan 2017[2]

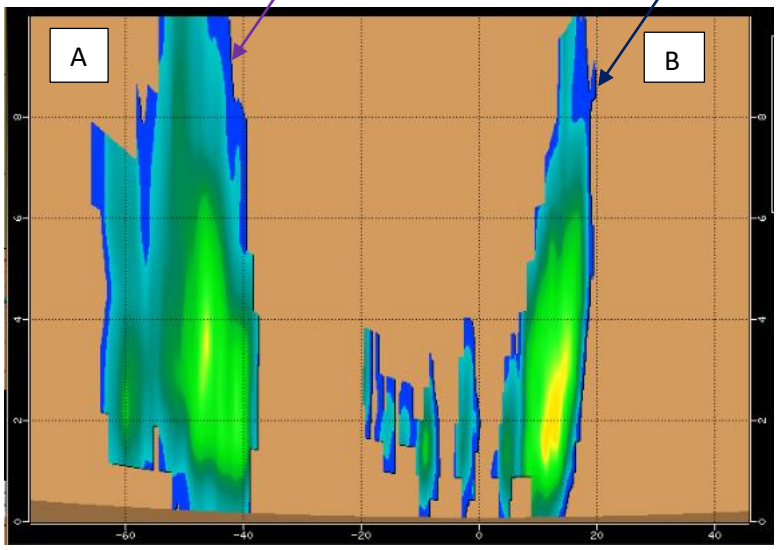


Cross section at red dashed line show that the height of highest intensity (yellow indicator) located between 2 km – 6 km. CAPPI 1km height image showed less intensity than CAPPI 2 km height.

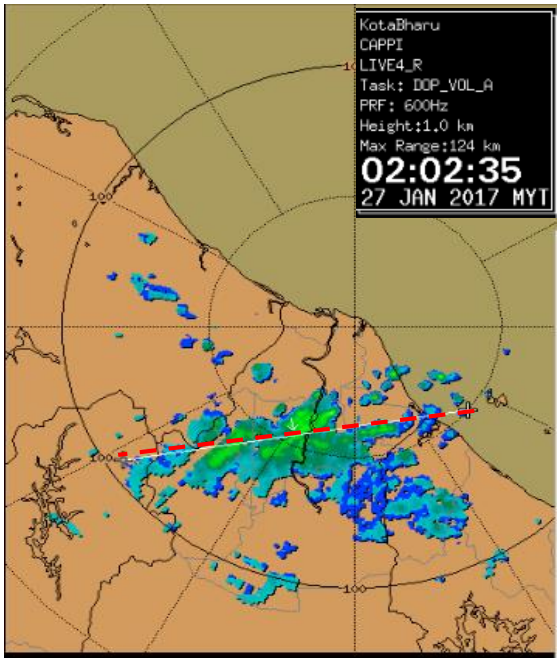
[2] Left images indicate CAPPI 1km, right images indicate CAPPI 2 km

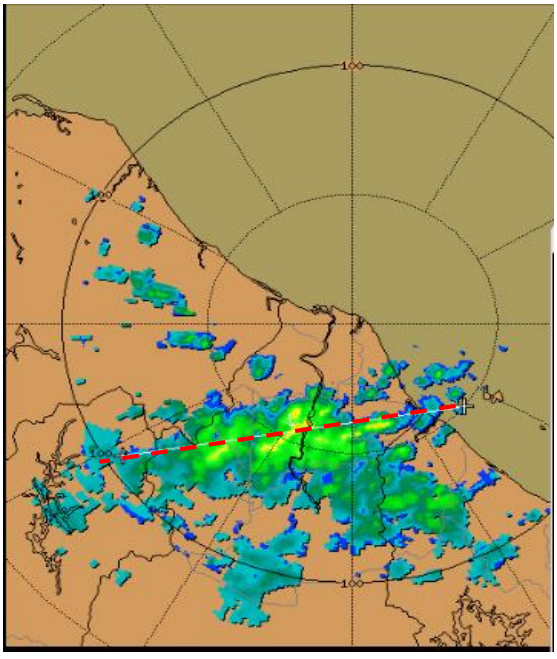


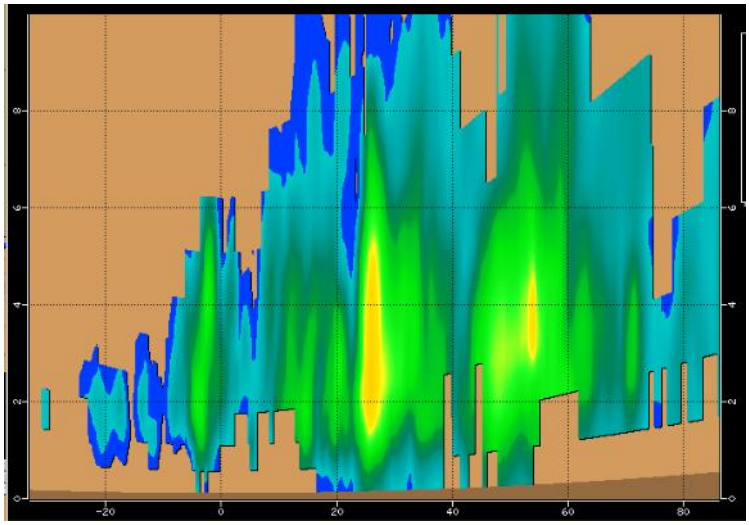




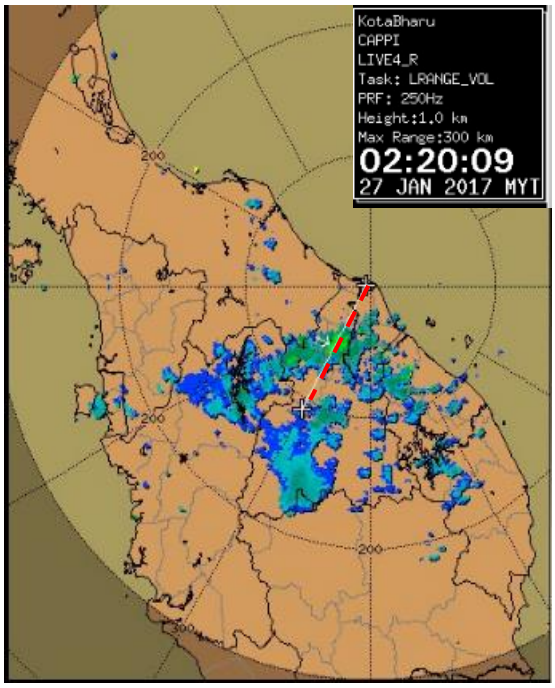
Cross section A at red dashed line show that the height of highest intensity (yellow indicator) located between 3 km – 4 km. Meanwhile, cross section B indicates the height of highest intensity located between 1.8 km – 4 km. CAPPI 1 km height image showed less intensity than CAPPI 2 km height.

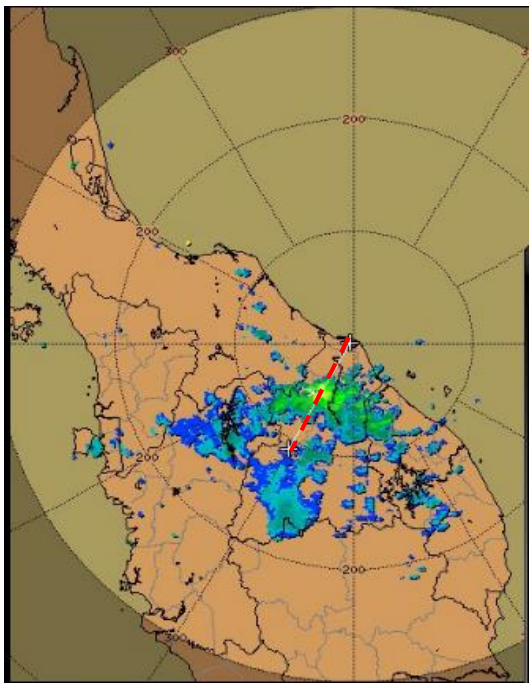


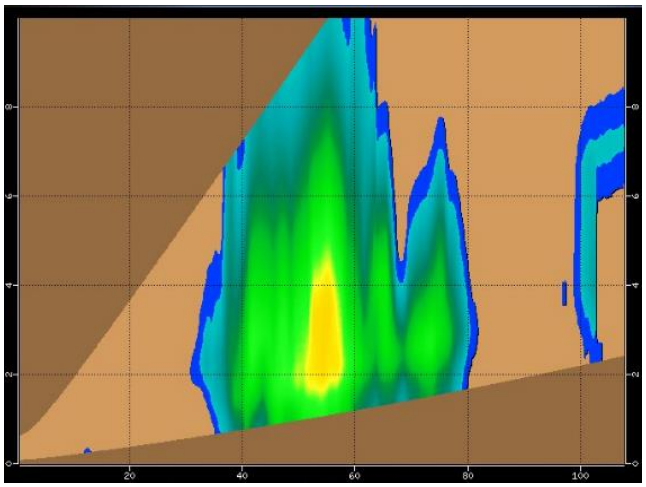




Cross section at red dashed line show that the height of highest intensity (yellow indicator) located between 1.7 km – 5.8 km. CAPPI 1 km height image showed less intensity than CAPPI 2 km height.







Cross section at red dashed line show that the height of highest intensity (yellow indicator) located between 2 km – 4 km. CAPPI 1 km height image showed less intensity than CAPPI 2 km height.

The images show that CAPPI height 2 km is better than 1 km. 2 km CAPPI available to detect precipitation cloud below 2 km. The development of intense precipitation located at 2 – 4 km height above ground level (AGL).

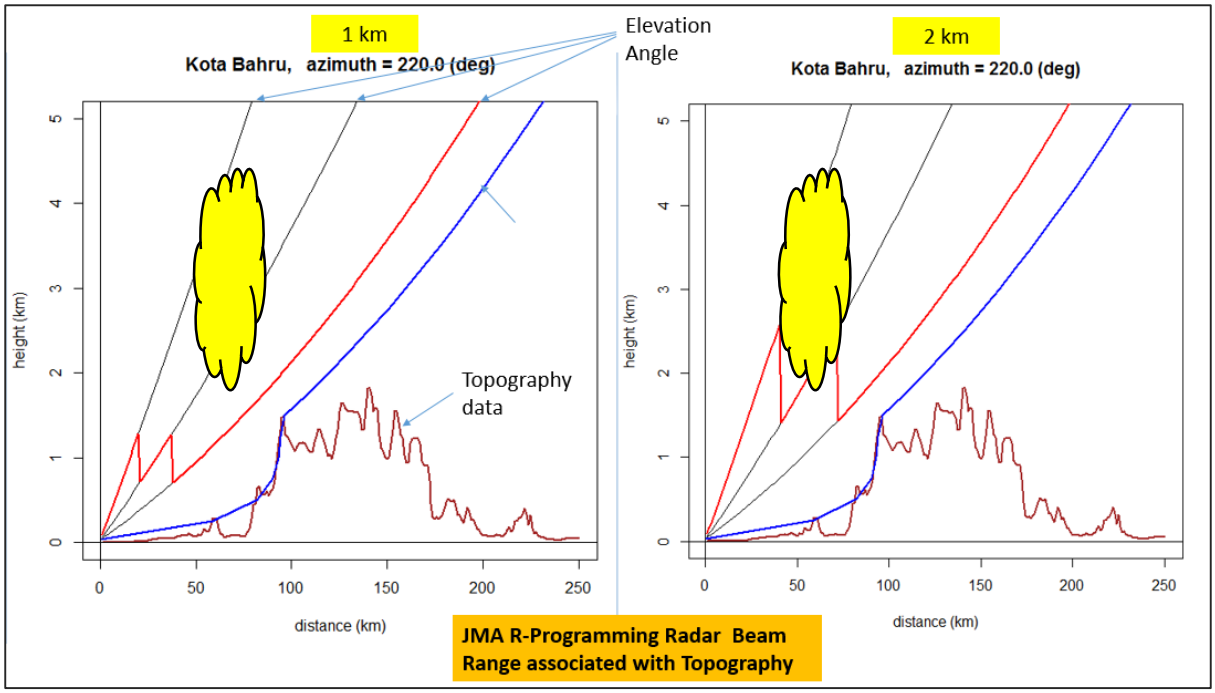


Figure 13: The illustration of intense cloud height at different CAPPI height.

From the comparison of CAPPI height related to intensity appeared in the image, proved that the less significant echoes radar images showed at 1 km CAPPI height. This is due to the scanning elevation angle cannot capture highest intensity at 2-4 km height as illustrated in the Figure 13.

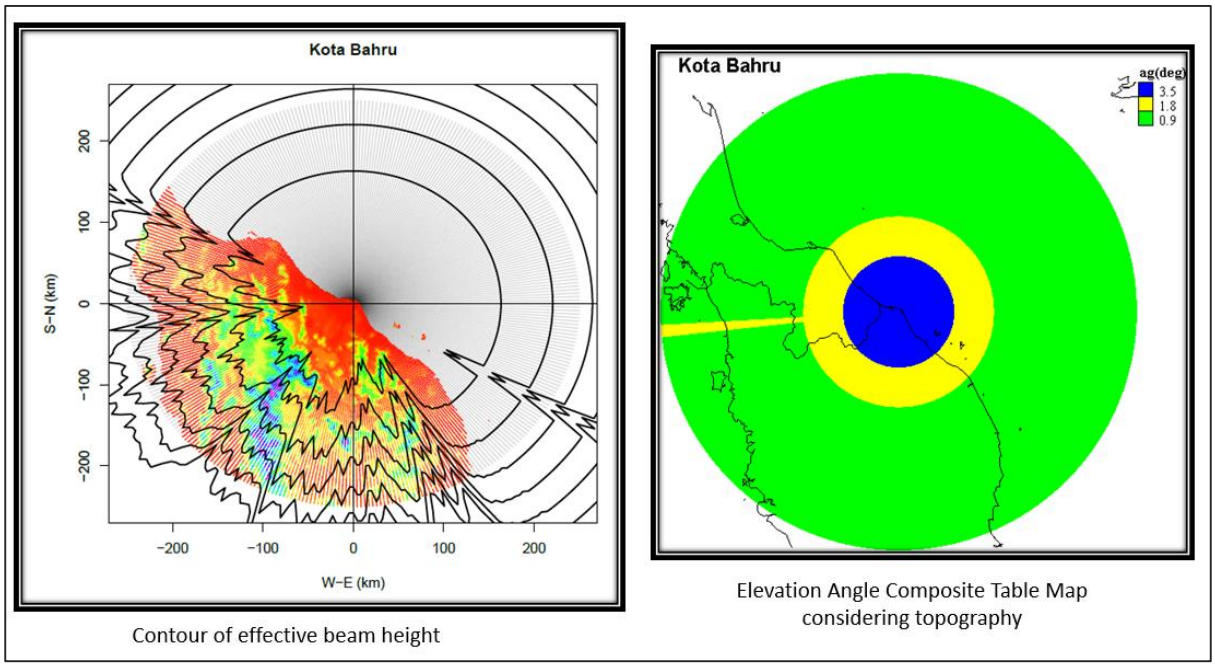
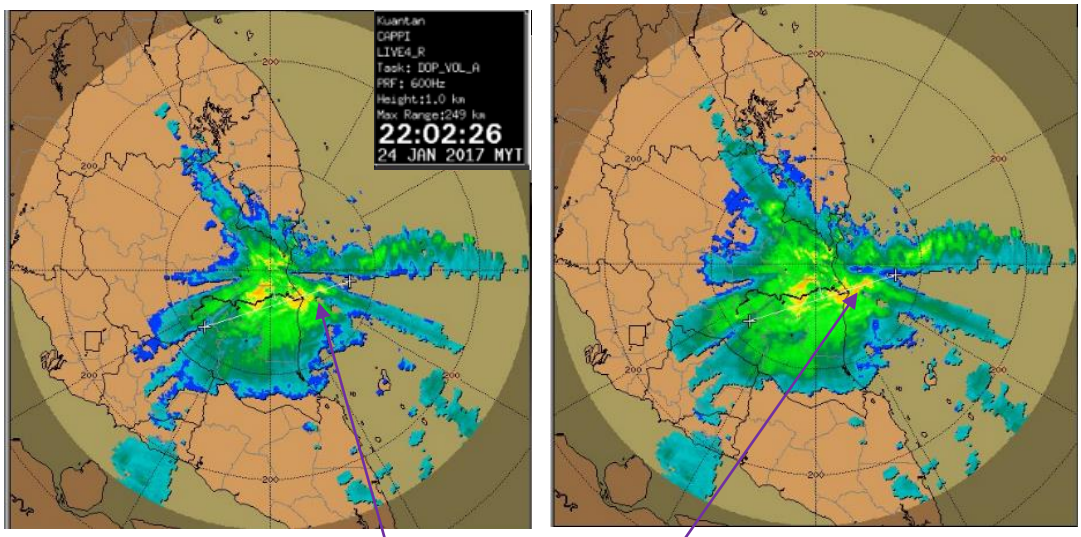
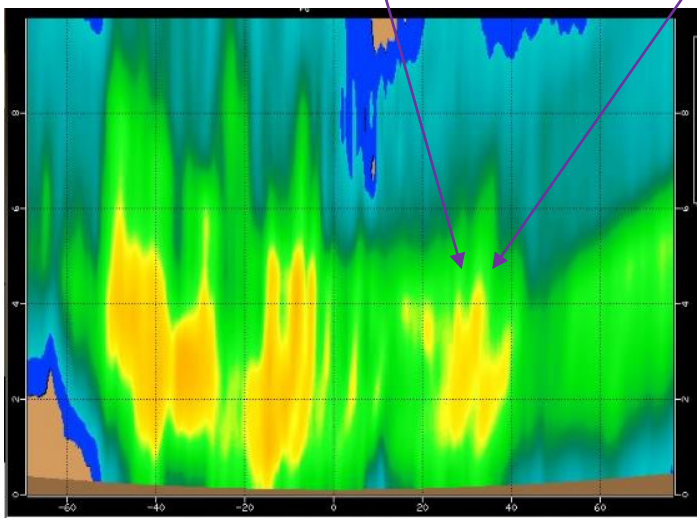


Figure 14: The map of topography and elevation angle composite table.

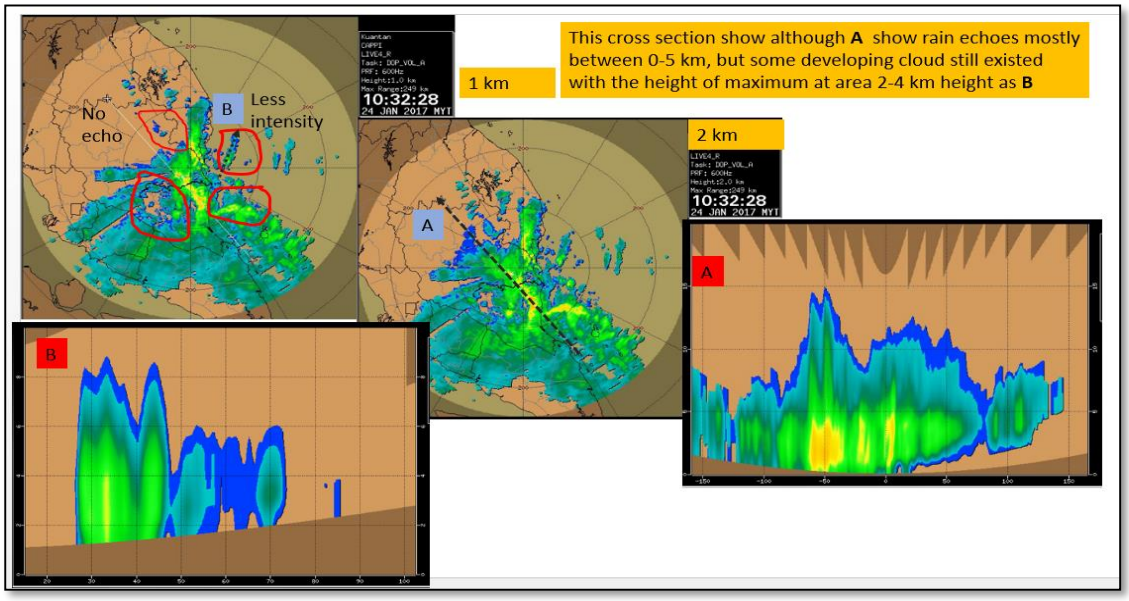
The software of JMA R-Programming Radar Beam Range associated with Topography in Figure 14 show that Kota Bahru radar station is less influenced by blockage problem since the scanning strategies at this radar is 0.9.1.8 and 3.5 to produce the CAPPI data.

c) Case Study 3: Kuantan Radar Station on the 24th Jan 2017[3]



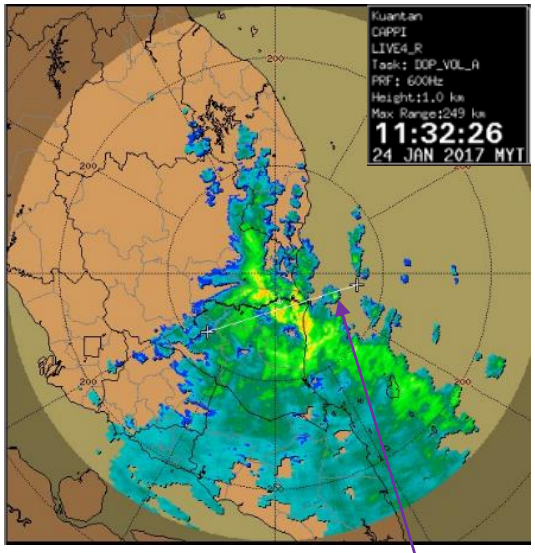


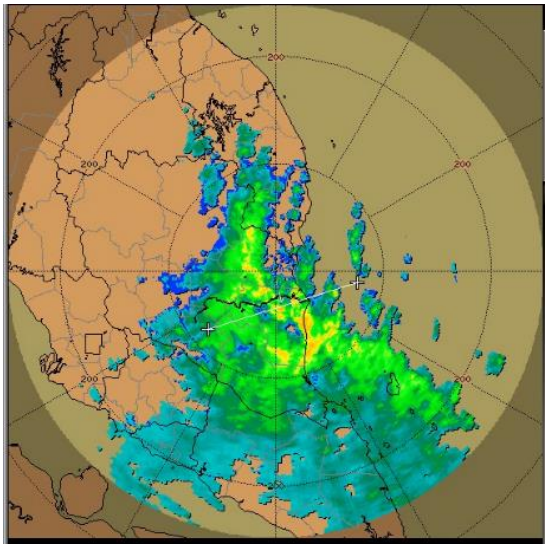
Cross section at purple straight line show that the height of highest intensity (yellow indicator) located between 1.5 km – 4.2 km. CAPPI 1 km height image showed less intensity than CAPPI 2 km height.

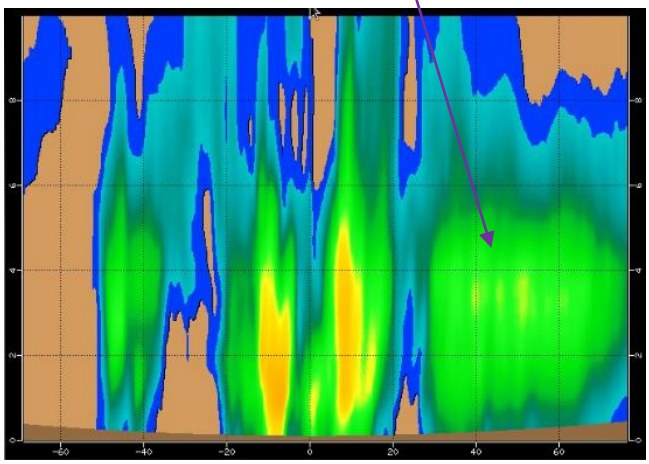


[3]Left images indicate CAPPI 1km, right images indicate CAPPI 2 km

The figure above show that intense rain cloud located at 0-5 km above the ground level from cross section A. Indeed, 2 km CAPPI height can capture this intense rain cloud. However, the developing rain clouds still existed between 2-4 km height which 1 km CAPPI cannot identify these high intensity of rain clouds as revealed in cross section B.







Cross section at purple straight line show that the height of highest intensity (yellow indicator) located between 2 – 4 km. CAPPI 1 km height image showed less intensity than CAPPI 2 km height.

The images show that CAPPI height 2 km is better than 1 km and it can still detect the precipitation cloud below 2 km. Most dominant developing rain cloud is located between 2 to 4 km. From the comparison of CAPPI height related to intensity appeared in the image, proved that the less significant echoes radar images showed at 1 km CAPPI height. This is due to the scanning elevation angle cannot capture highest intensity at 2-4 km height as illustrated in the Figure 15.

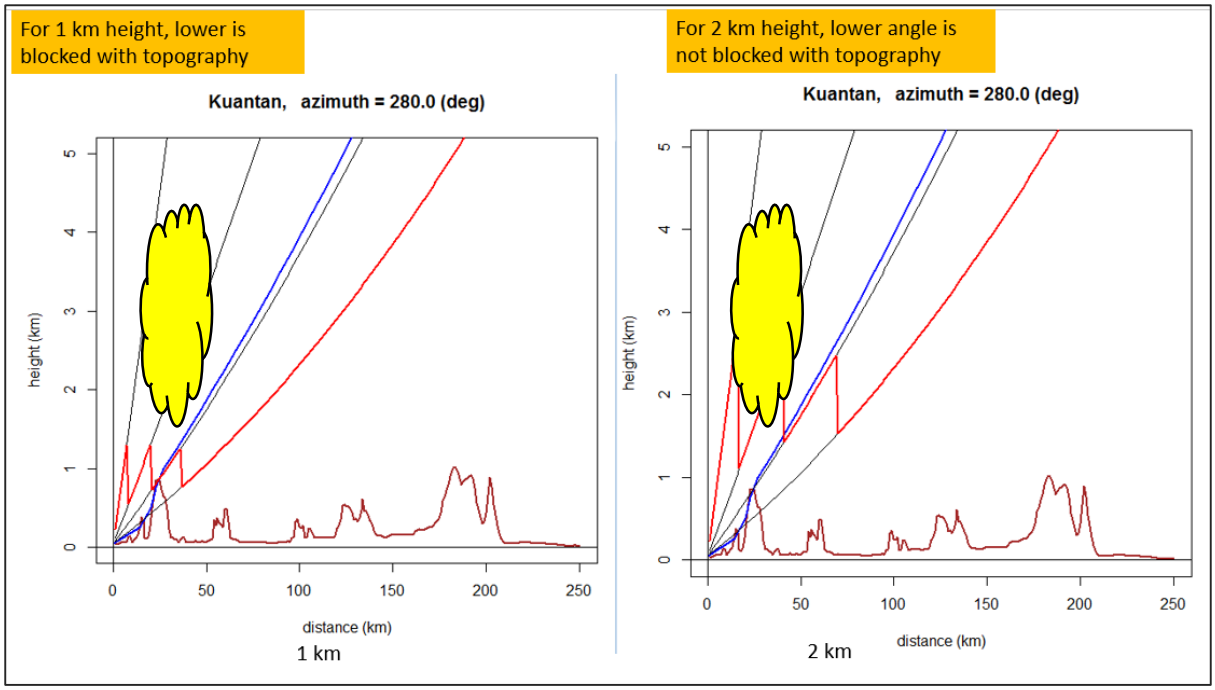


Figure 15: The illustration of intense cloud height at different CAPPI height.

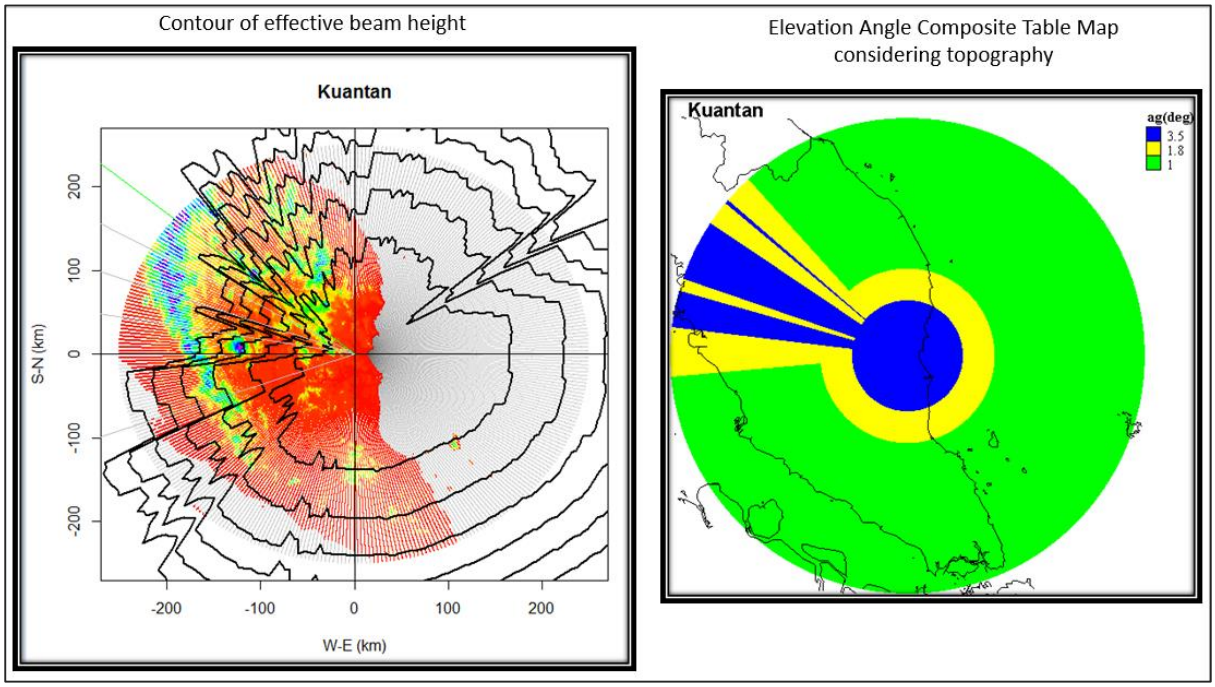
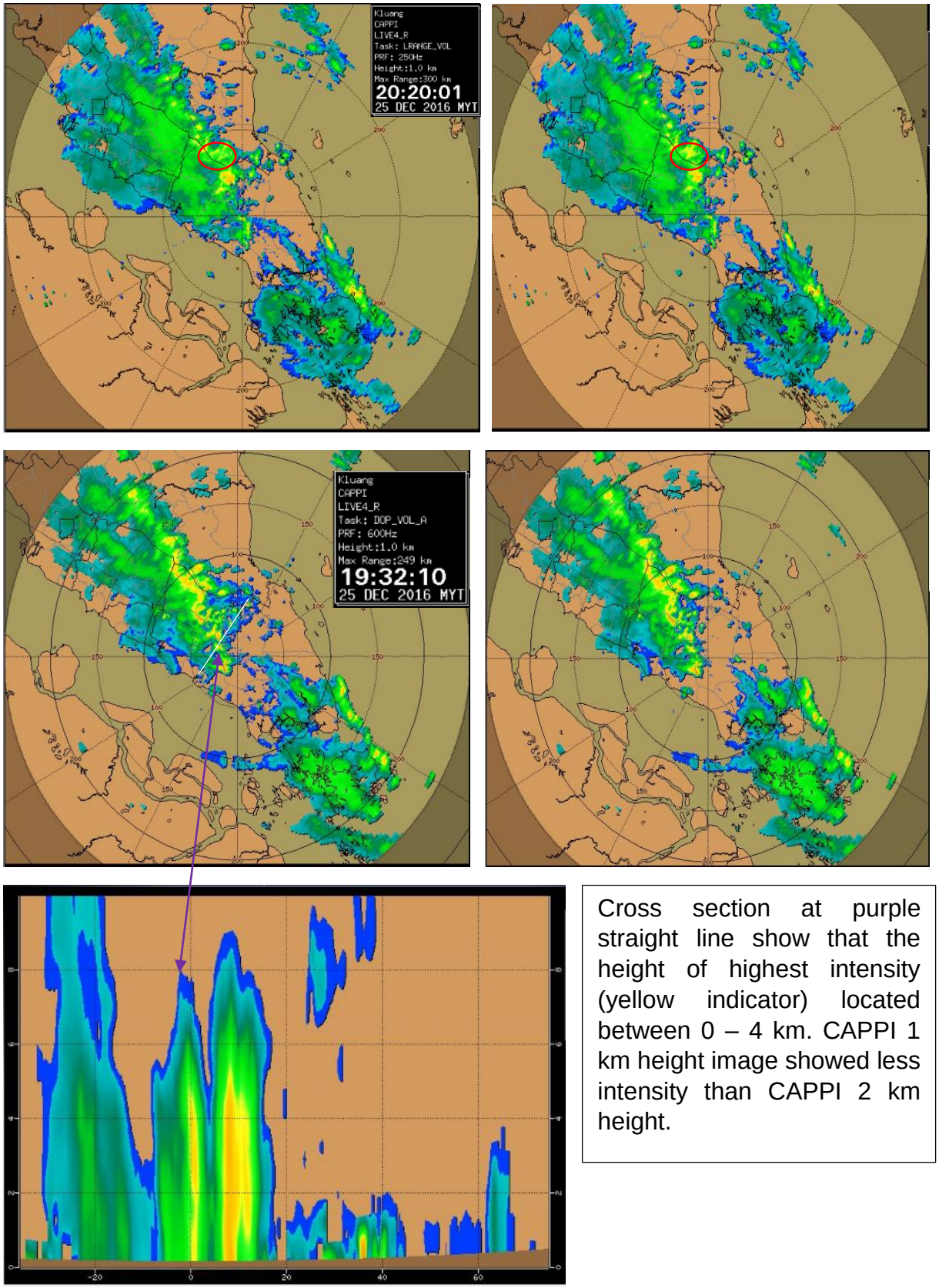


Figure 16: The map of topography and elevation angle composite table.

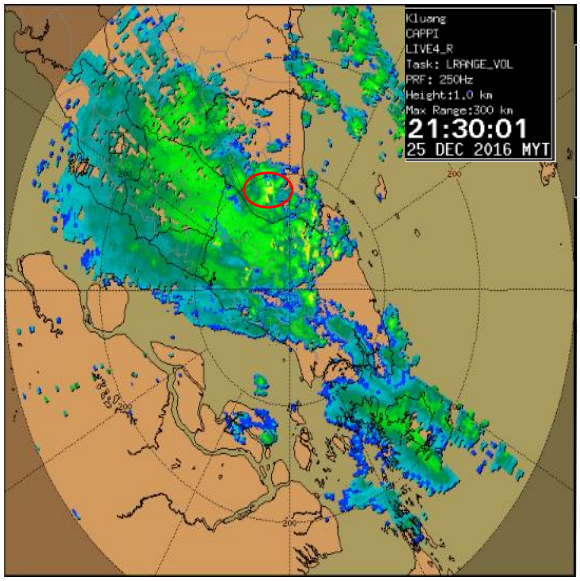
The software of JMA R-Programming Radar Beam Range associated with Topography in Figure 16 show that Kuantan radar station is influenced by upper elevation angle data mostly at the azimuth 280-330 degree since the radar beam is blocked with the Titiwangsa Range although the scanning strategies at this radar is 1.0, 1.8 and 3.5 to produce the CAPPI data. Hence, some radar data will be blocked and contaminated with ground clutter if the CAPPI height is setting to 1 km.

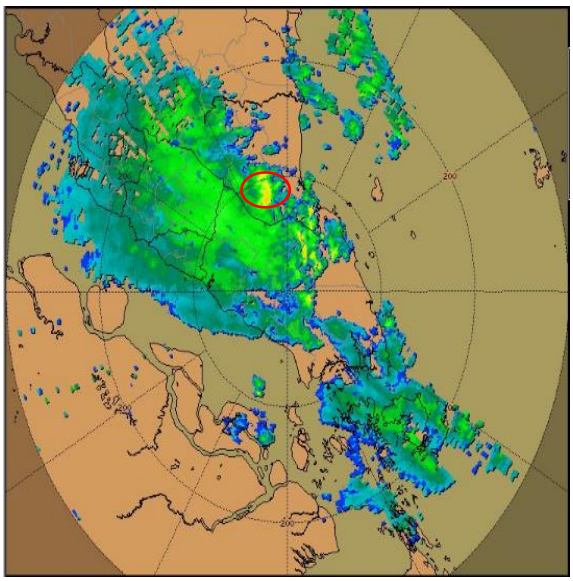
d) Case Study 4: Kluang Radar Station on the 25th Dec 2016[4]

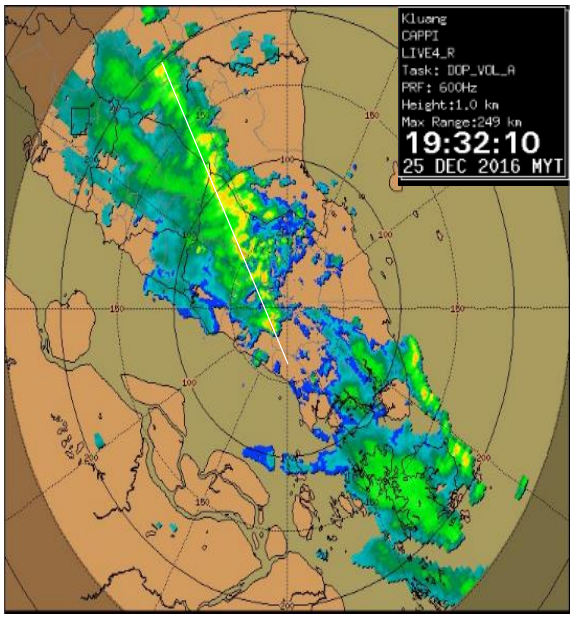


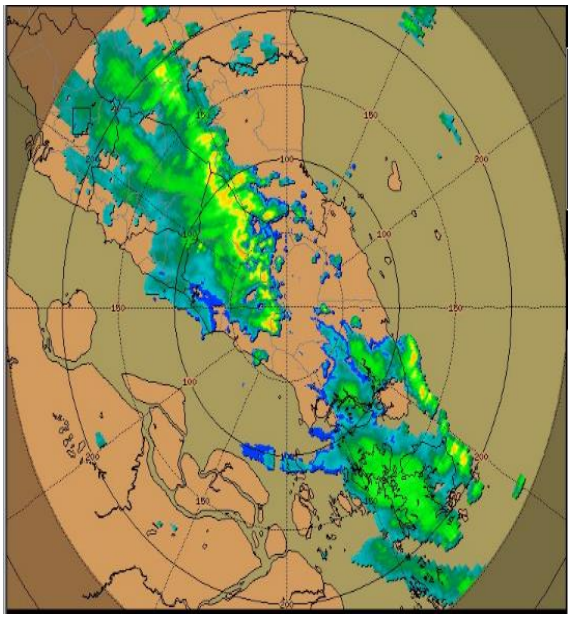
Cross section at purple straight line show that the height of highest intensity (yellow indicator) located between 0 – 4 km. CAPPI 1 km height image showed less intensity than CAPPI 2 km height.

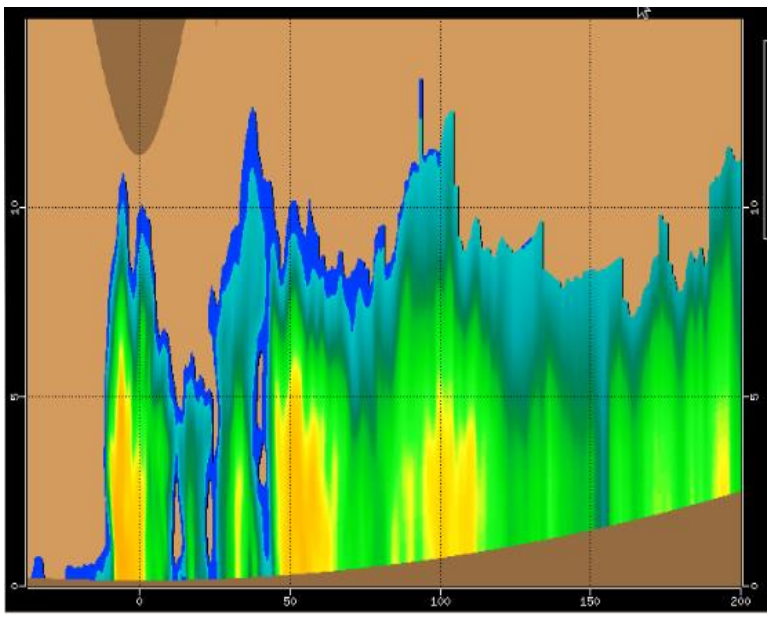
[4] Left images indicate CAPPI 1km, right images indicate CAPPI 2 km











Cross section at white straight line show that the height of highest intensity (yellow indicator) located between 0 – 5 km. CAPPI 2 km height image showed more intensity than CAPPI 1 km height.

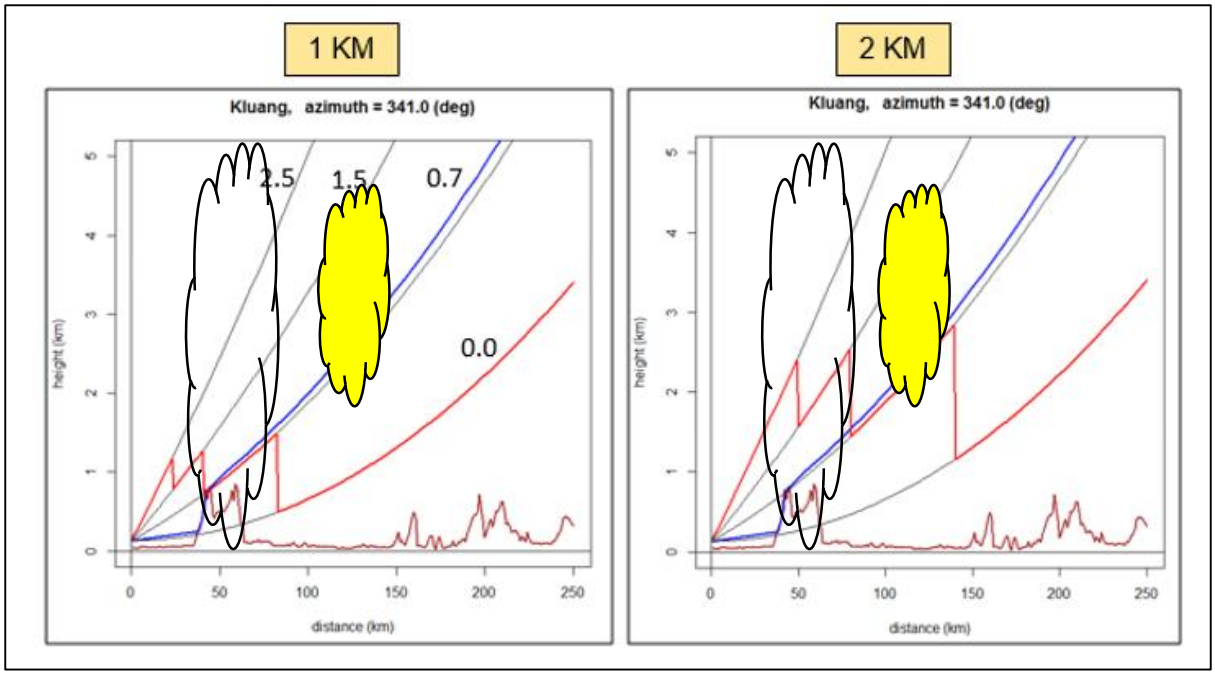


Figure 17: The illustration of intense cloud height at different CAPPI height.

Figure 17 shows that 2 km CAPPI available to detect precipitation cloud below 2 km. Some developed rainfall cloud is located at 2 - 4 km height. Hence, 1 km CAPPI height cannot detect precipitation cloud which is in the range of 2-4 km as illustrated in the figure above.

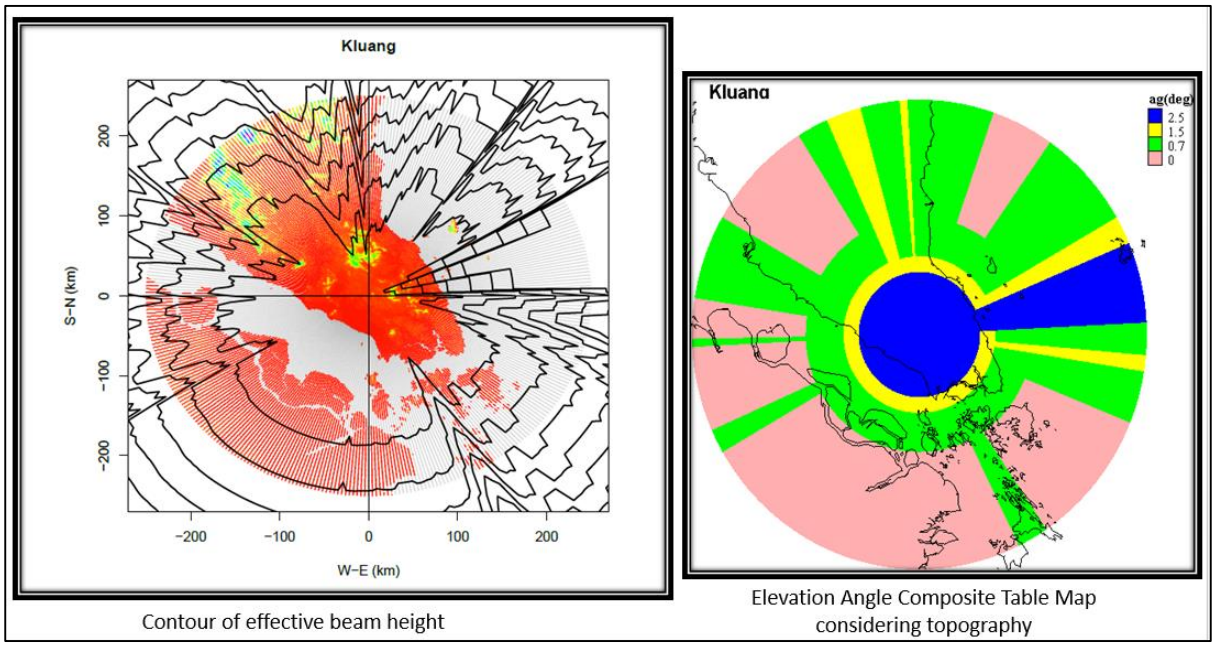
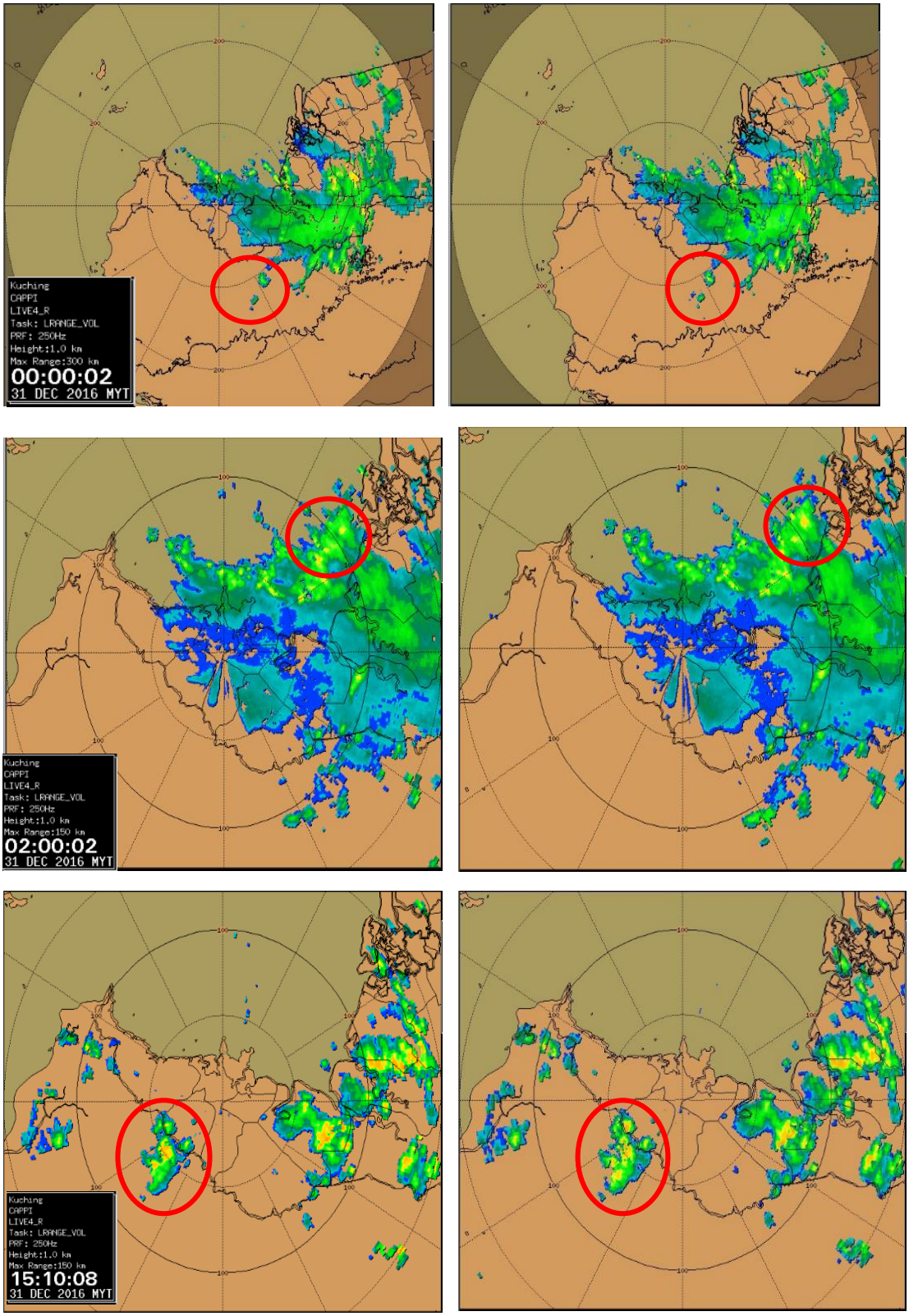


Figure 18: The map of topography and elevation angle composite table.

The software of JMA R-Programming Radar Beam Range associated with Topography in Figure 18 show that Kluang radar station has blockage problem at the azimuth 60-90 degree since the radar beam is blocked with the hill. Hence, some radar data will contaminated with ground clutter if the CAPPI height is setting to 1 km.

e) Case Study 5: Kuching Radar Station on the 31st Dec 2016[5]



The images show that CAPPI height 2 km is better than 1 km. The image of 1 km CAPPI is less intense compared to 2 km height.

[5] Left images indicate CAPPI 1km, right images indicate CAPPI 2 km

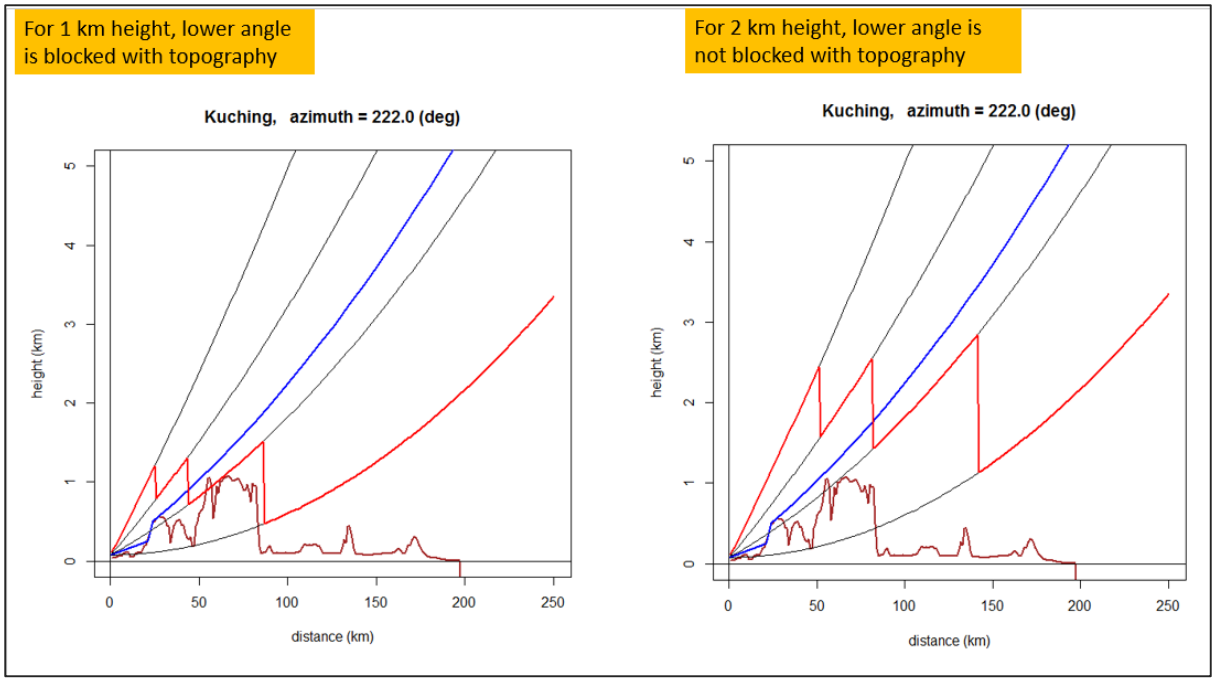


Figure 19: CAPPI 1 km is more blocked with topography data at azimuth 222 degree.

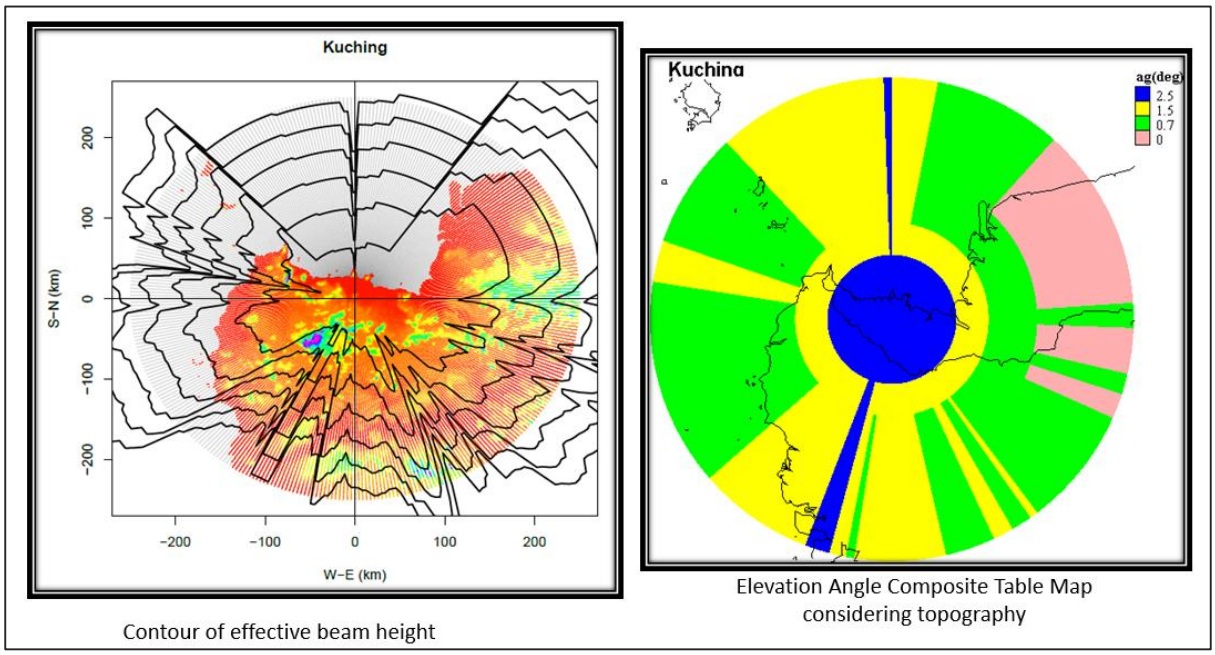
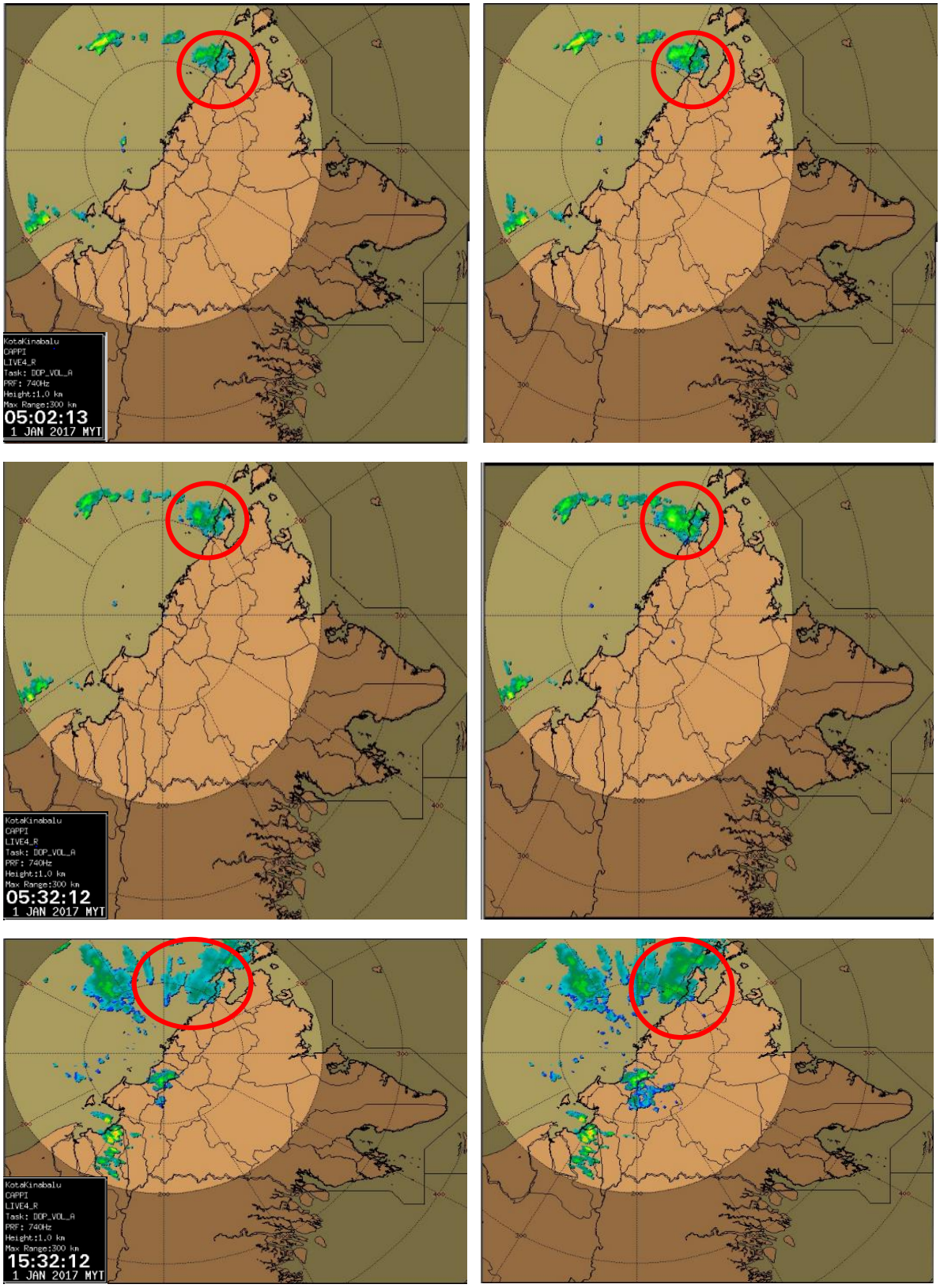


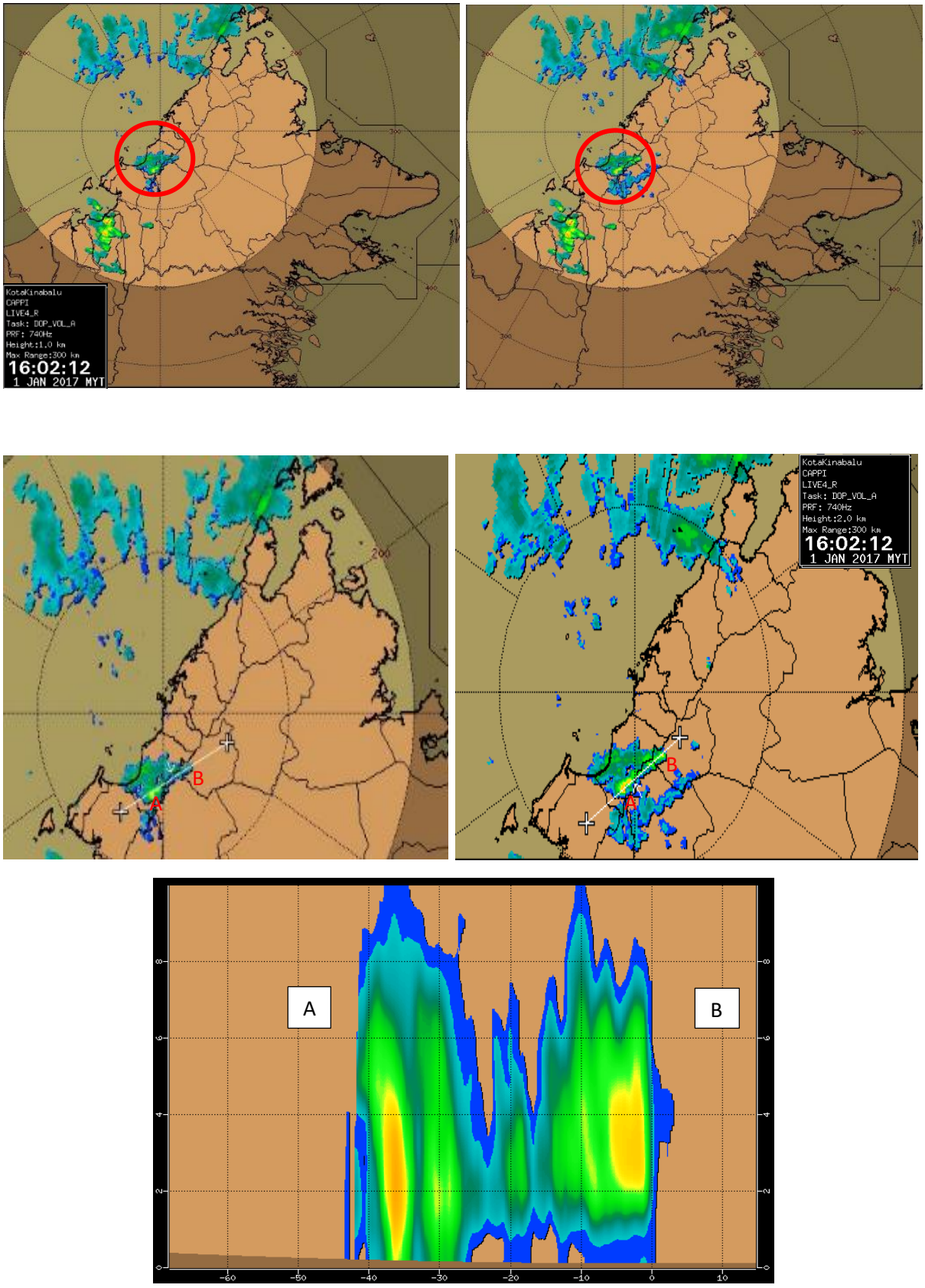
Figure 20: The map of topography and elevation angle composite table.

The software of JMA R-Programming Radar Beam Range associated with Topography in Figure 20 shows that Kuching radar station is influenced by upper elevation angle data mostly at the azimuth 200-250 degree since the radar beam is blocked with the mountain. The scanning strategies at this radar is 0.0, 0.7, 1.5 and 2.5 degree to produce the CAPPI data. Hence, some radar data will be blocked and contaminated with ground clutter if the CAPPI height is setting to 1 km.

f) Case Study 6: Kota Kinabalu Radar Station on the 1st Jan 2017[6]



[6] Left images indicate CAPPI 1km, right images indicate CAPPI 2 km



The cross section A revealed that 2 km CAPPI available to detect precipitation cloud below 2 km. Some developed rainfall cloud is located at 2 - 4 km height. Hence, 1 km CAPPI height cannot detect precipitation cloud which is in the range of 2-4 km as shown in the cross section B.

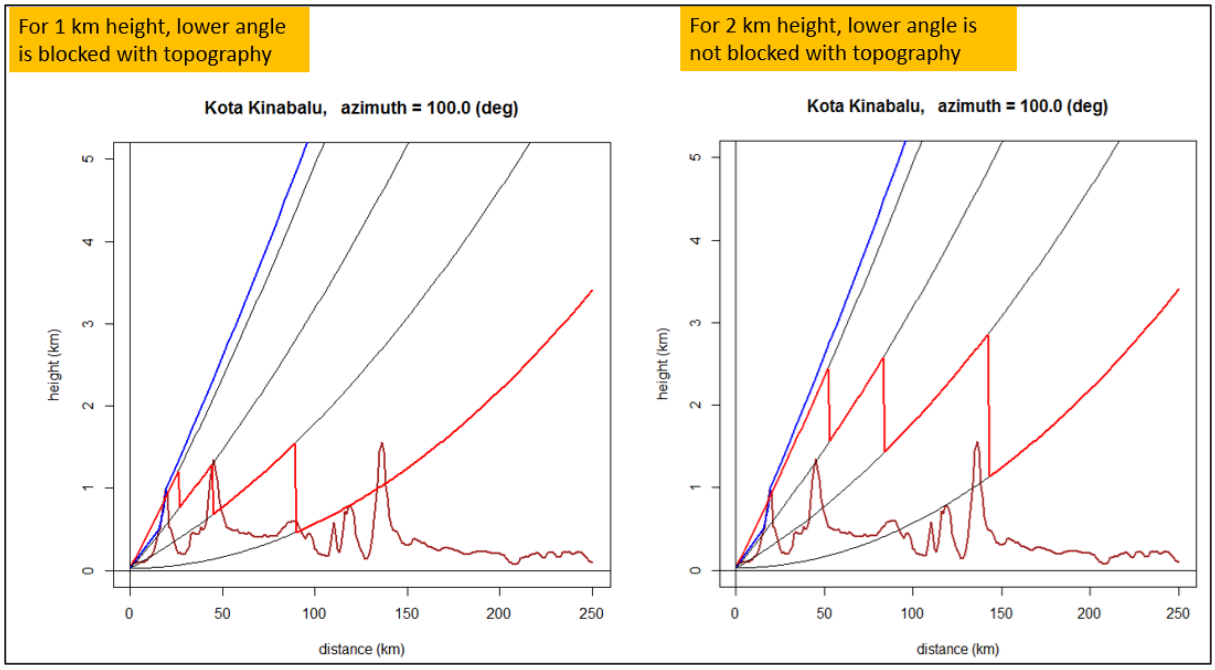


Figure 21: CAPPI 1 km is more blocked with topography data at azimuth 100 degree.

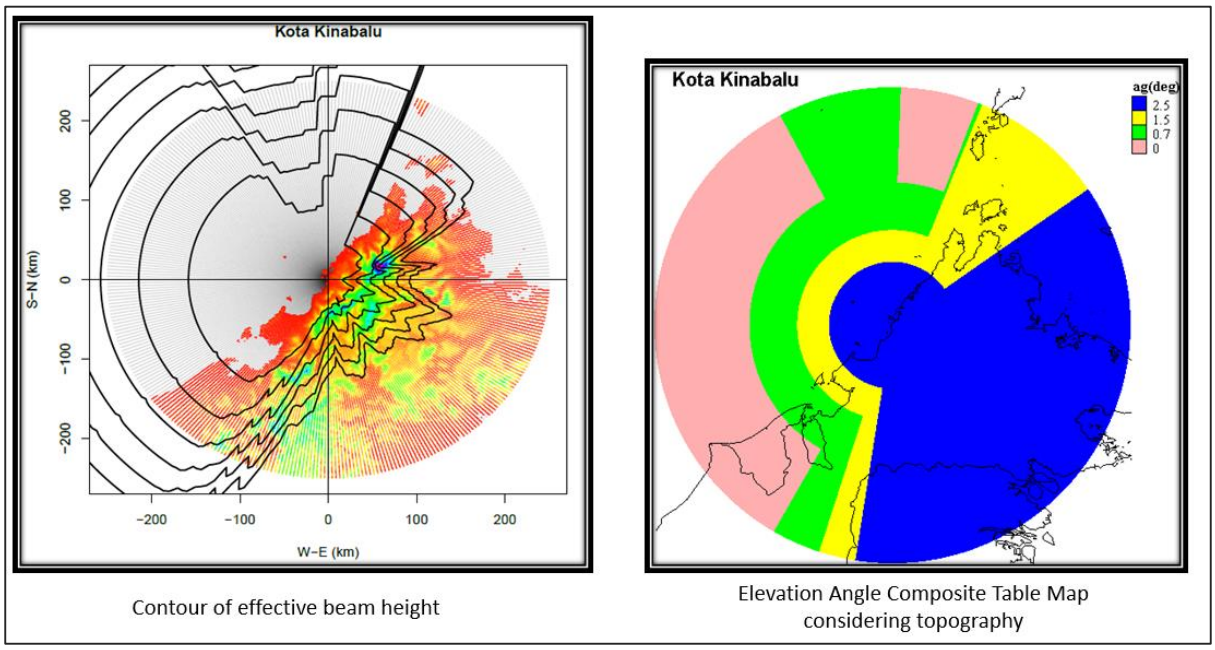


Figure 22: The map of topography and elevation angle composite table.

The software of JMA R-Programming Radar Beam Range associated with Topography in Figure 22 shows that Kota Kinabalu radar station is influenced by upper elevation angle data mostly at the eastern part from radar since the radar beam is blocked with the Crocker Range. The scanning strategies at this radar is 0.0, 0.7, 1.5 and 2.5 degree to produce the CAPPI data. Hence, some radar data will be blocked and contaminated with ground clutter if the CAPPI height is setting to 1 km.

g) Case Study 7: Kluang Radar Station on the 9th Feb 2017

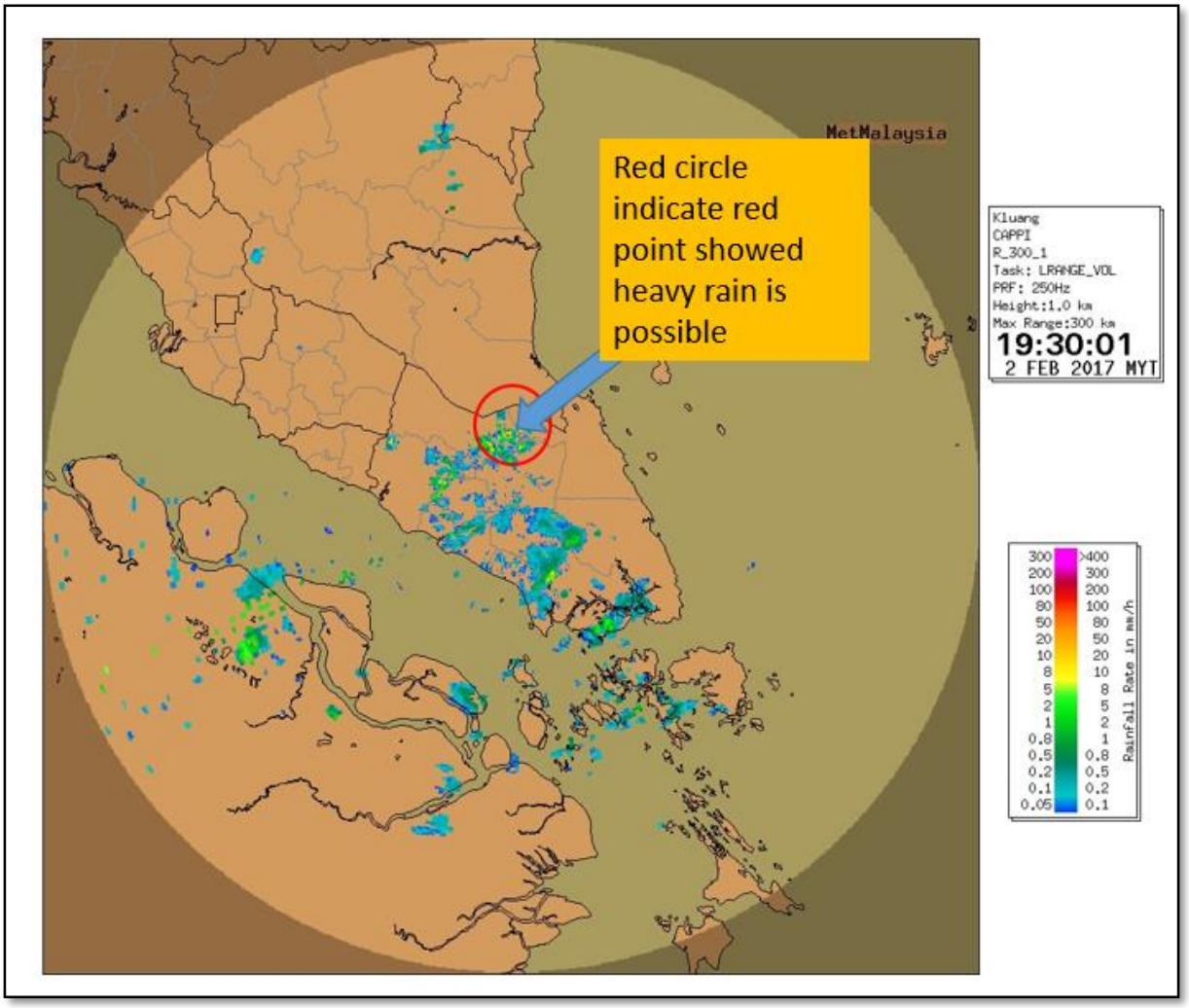


Figure 23: Radar image of Kluang station indicated possible heavy rain echoes.

Using 1 km CAPPI height, Figure 23 show the heavy rain is possible at the red circle. When checking all the images at different CAPPI height, CAPPI 1 km is more contaminated with ground clutter (Figure 24) since the Doppler data not show any significant of adverse weather at that area (Figure 25). Vertical cross-section at the area described that the high of radar reflectivity which indicated the ground clutter sourced from topography (Figure 26). We can see the differentiation between clutter and developing rain clouds as rain cloud pattern are generally in uniform pattern (Figure 27).

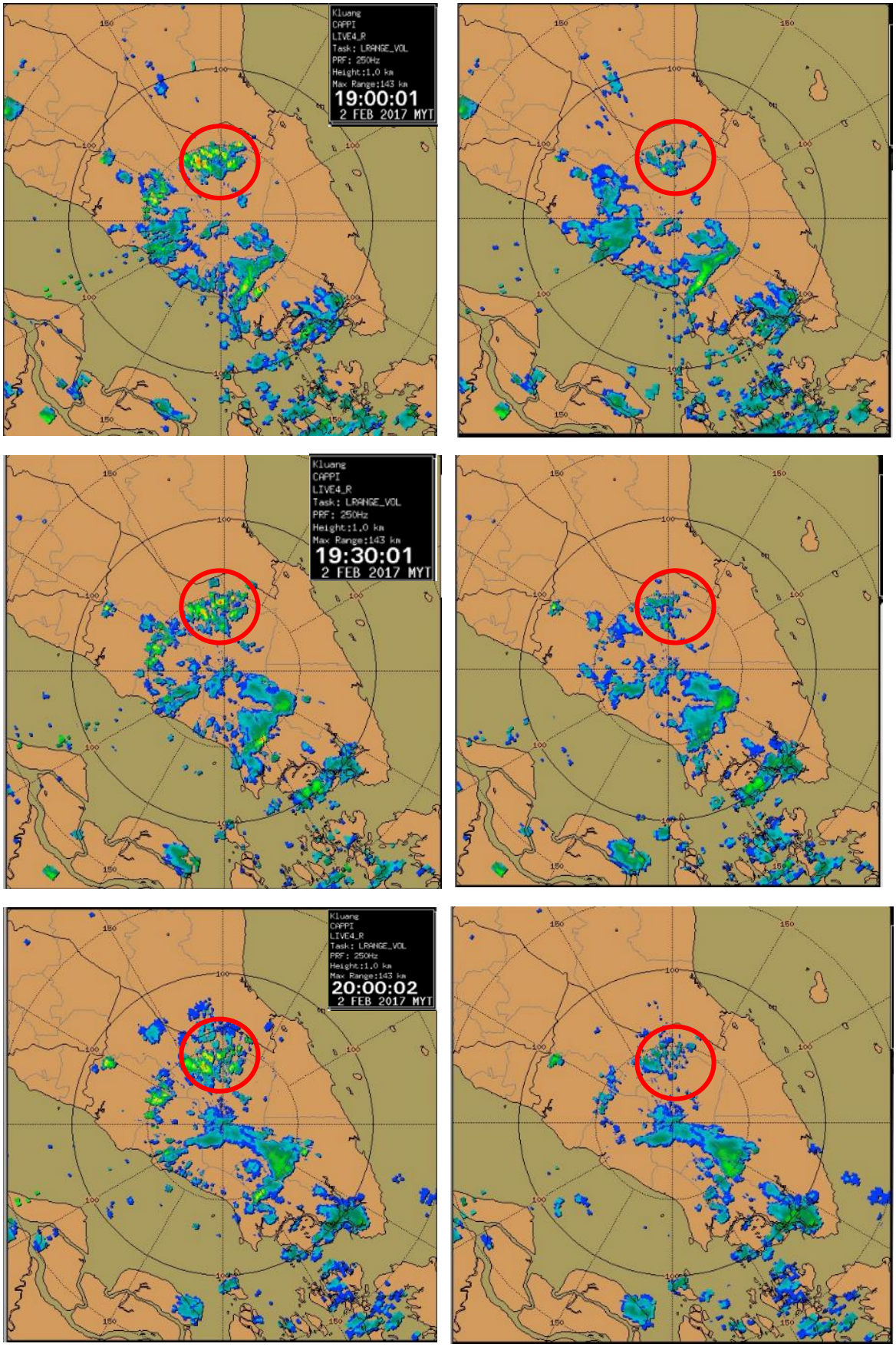


Figure 24: The left image(1 km) is more contaminated with ground clutter compared the right image (2 km) due to the lower radar beam intersect with topography.

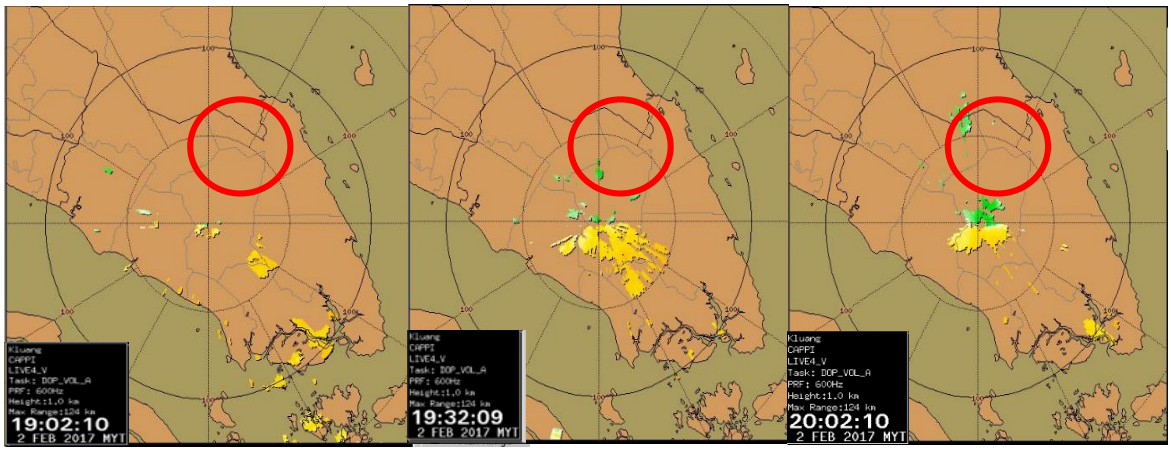


Figure 25: These velocity images not show any signature of severe weather event.

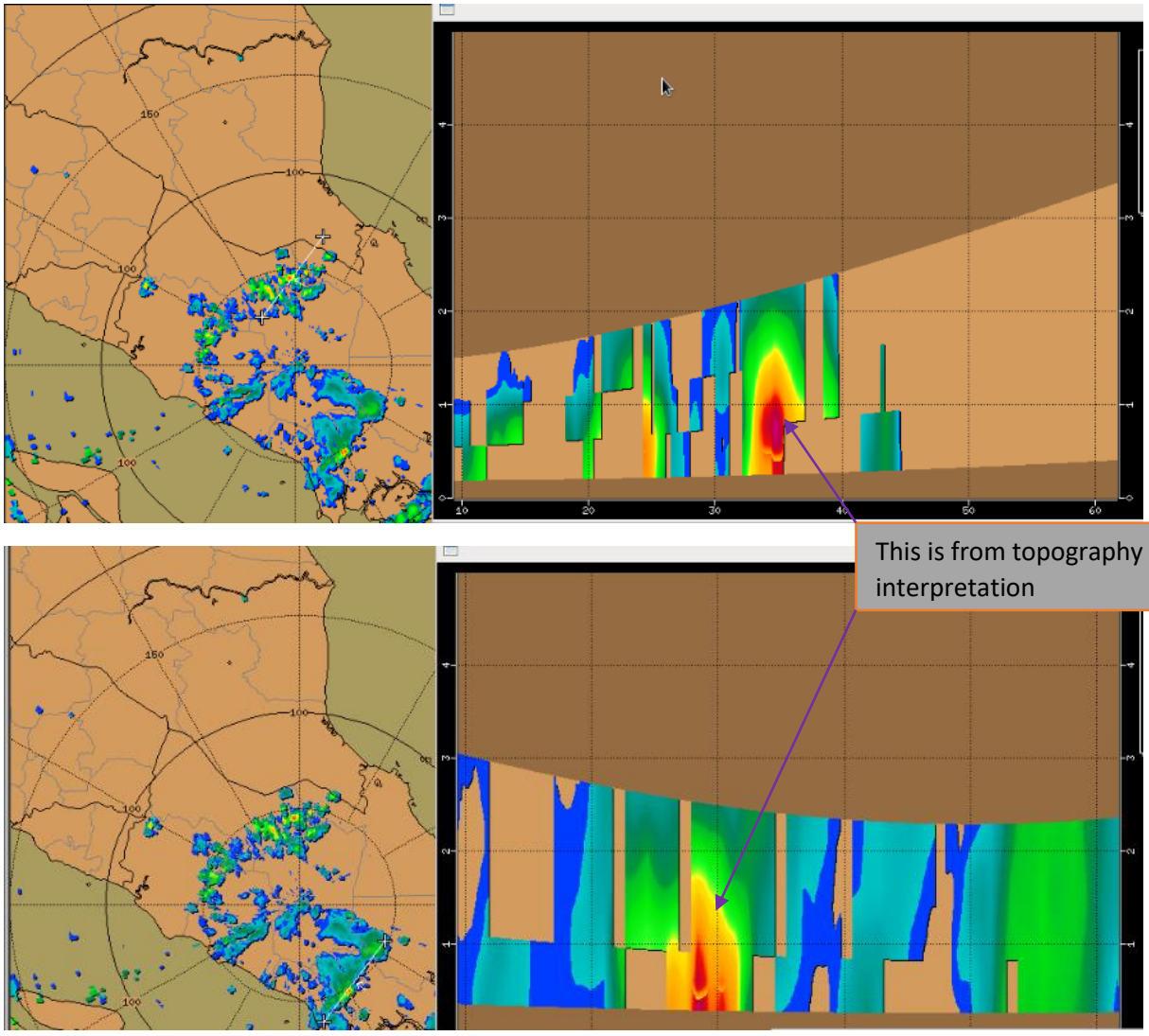


Figure 26: Using IRIS vertical cross-section at two areas, the highest reflectivity is reflected from the topography data not from the hydrometeor properties.

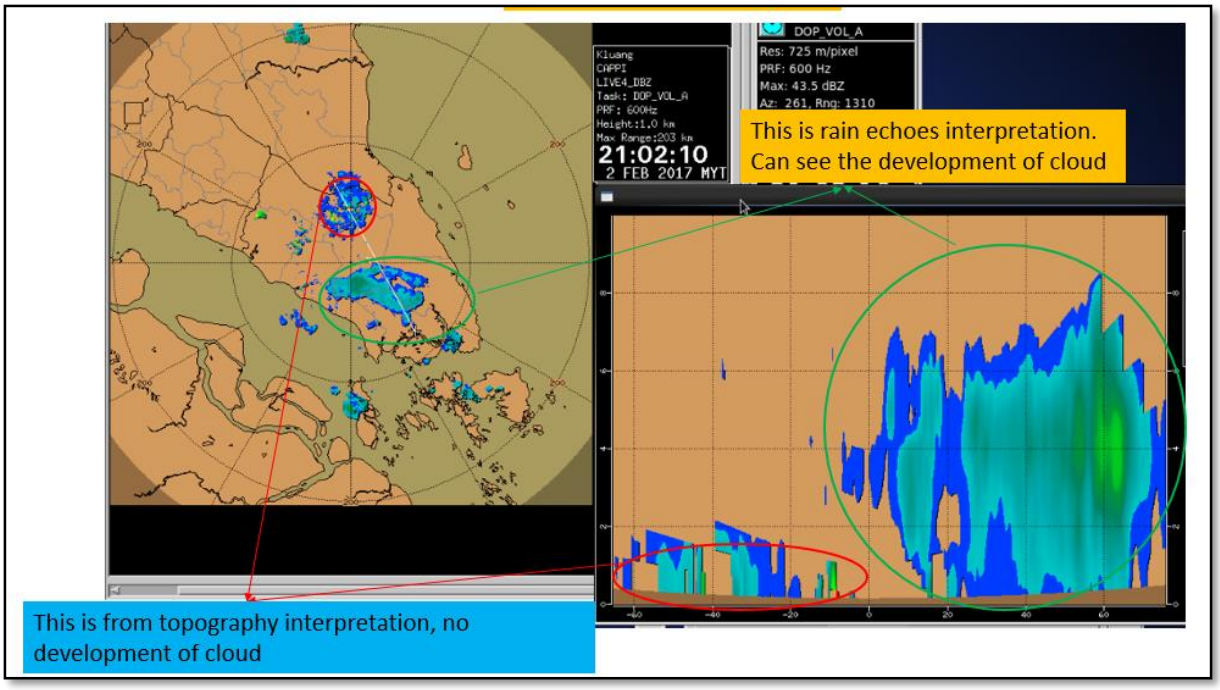


Figure 27: The comparison between rainfall and topography interpretation by making vertical cross section verify that the development of cloud can be identified using this tools. Instead, the topography data only show not uniform pattern as the radar reflect the trees and ground.

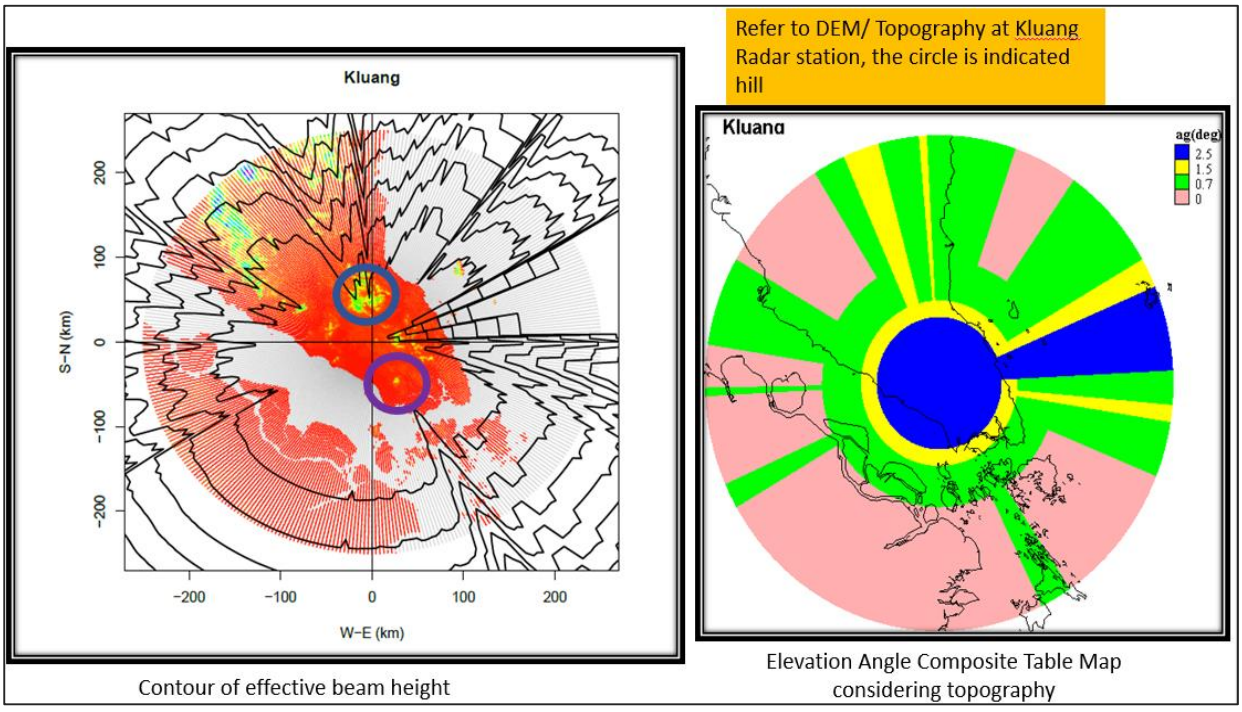


Figure 28: The map of topography and elevation angle composite table.

The topography map in Figure 28 from the elevation data using JMA Radar Beam Visibility Analysis Tools at the blue circle location prove that the highest elevation data located at those areas.

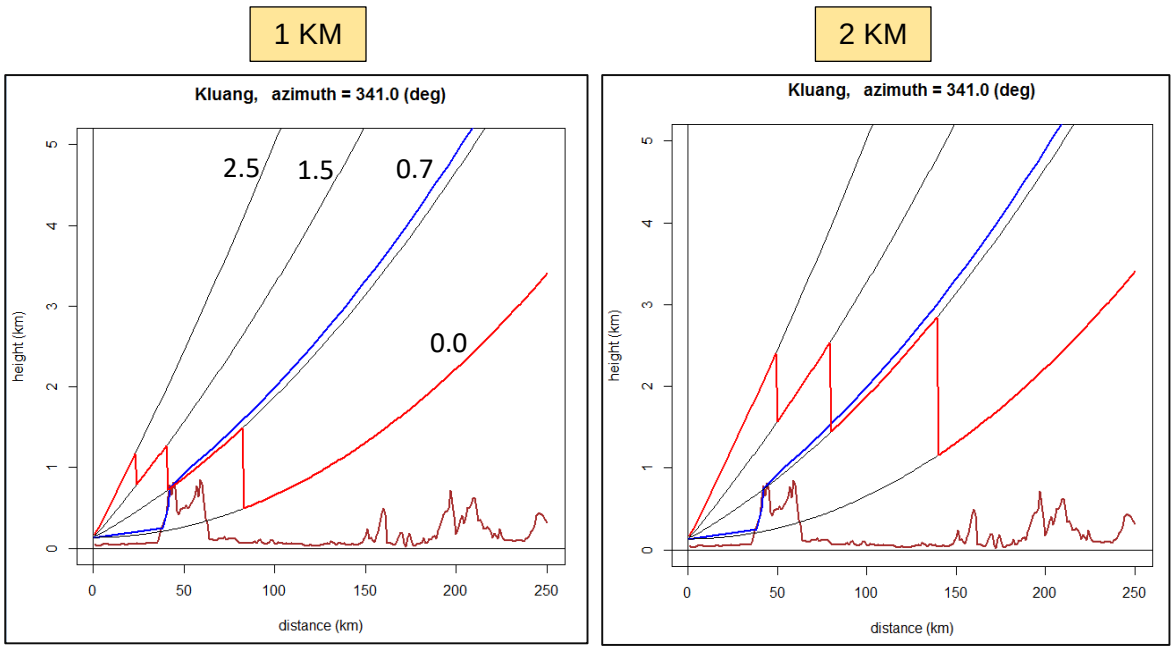


Figure 29: CAPPI 1 km is more blocked with topography data at azimuth 341 degree.

The both images in Figure 29 show the radar beam analysis tool at azimuth 341.0 degree which the ground clutter existed at the upper blue circle at the topography map. Using 1 km CAPPI height, the radar beam (blue line) will intersect with topography data (brown line) and data of elevation angle 0.7 degree (red line), hence more ground clutter existed on the radar images. In comparison, 2 km CAPPI height not intersect with topography data for each elevation angles.

4.0 Conclusions

- CAPPI 2 km is better than 1 km since some developing precipitation clouds at highest intensity are located at 2-4 km during Northeast Monsoon.
- Although the high intensity showed below 2 km above ground level, the CAPPI height of 2 km still showing the intense radar images as not all developing cloud located below than 2 km.
- 1 km CAPPI height cannot detect the intense precipitation cloud which sometimes beyond 1 km above ground level.
- Most radar stations locate near the hill, hence radar coverage is limited due to the blockage from topography.
- Ground clutter echoes appear more at 1 km CAPPI height compare to 2 km height due to the lowest radar beam intersect with topography data. Furthermore, in the super-refraction and ducting condition, the radar beam become lower than actual, hence the radar images possibly more contaminated with ground clutter.

5.0 References

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Website:-

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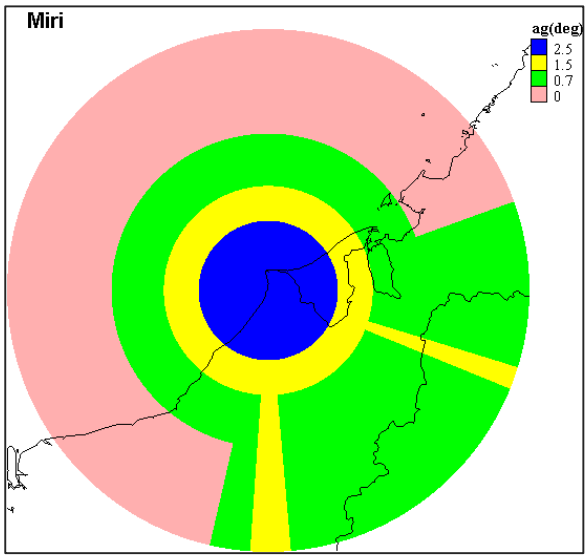
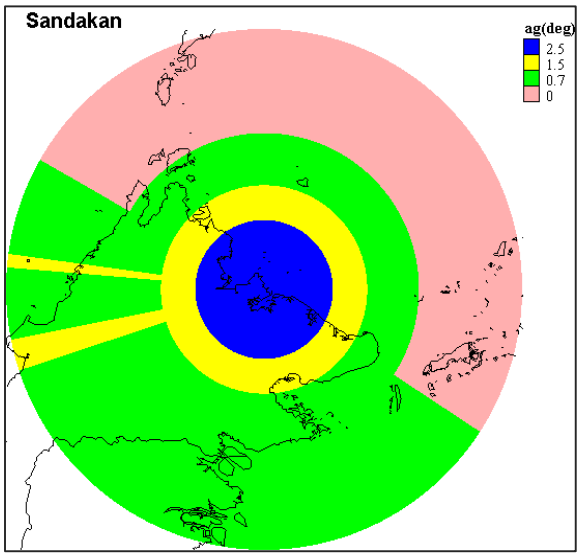
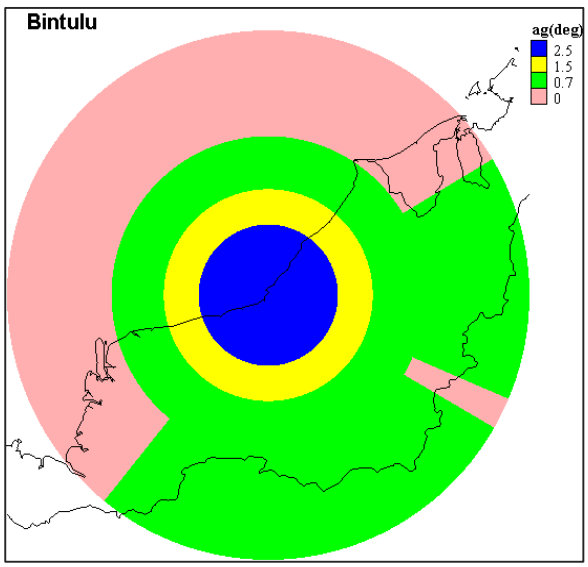
http://www.radar.mcgill.ca/science/ex-instrument/ex-scanning-radar.html

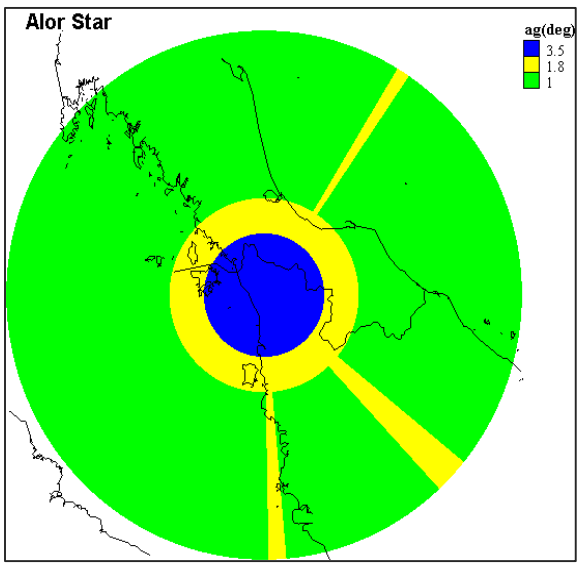
APPENDICES

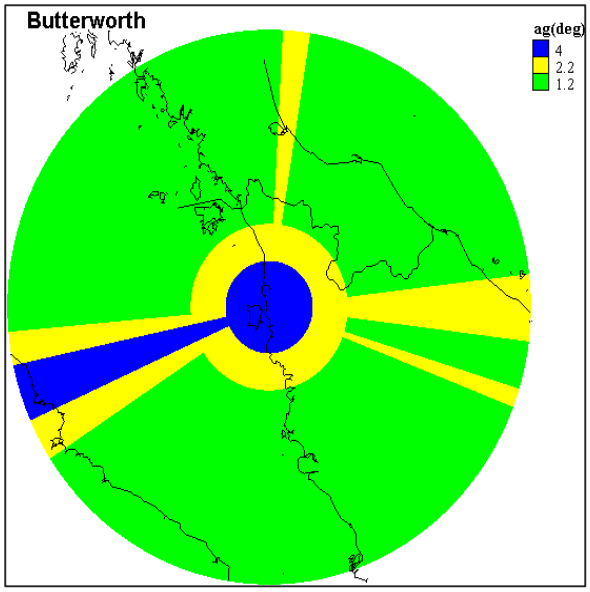
Elevation Angle Composite Table Considering Topography Data

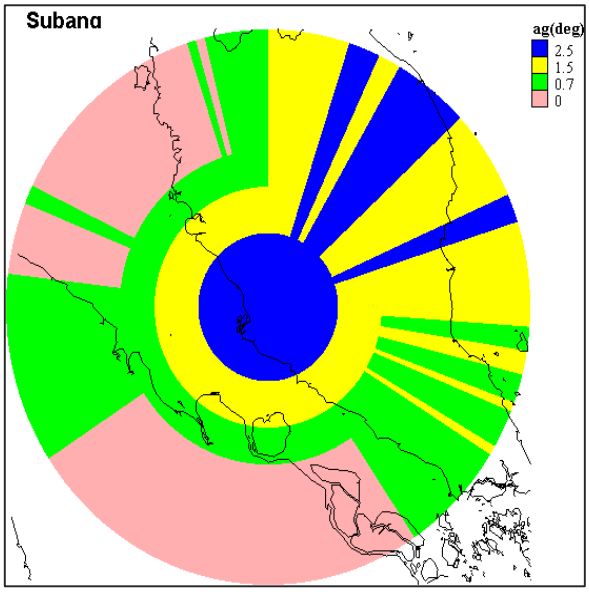




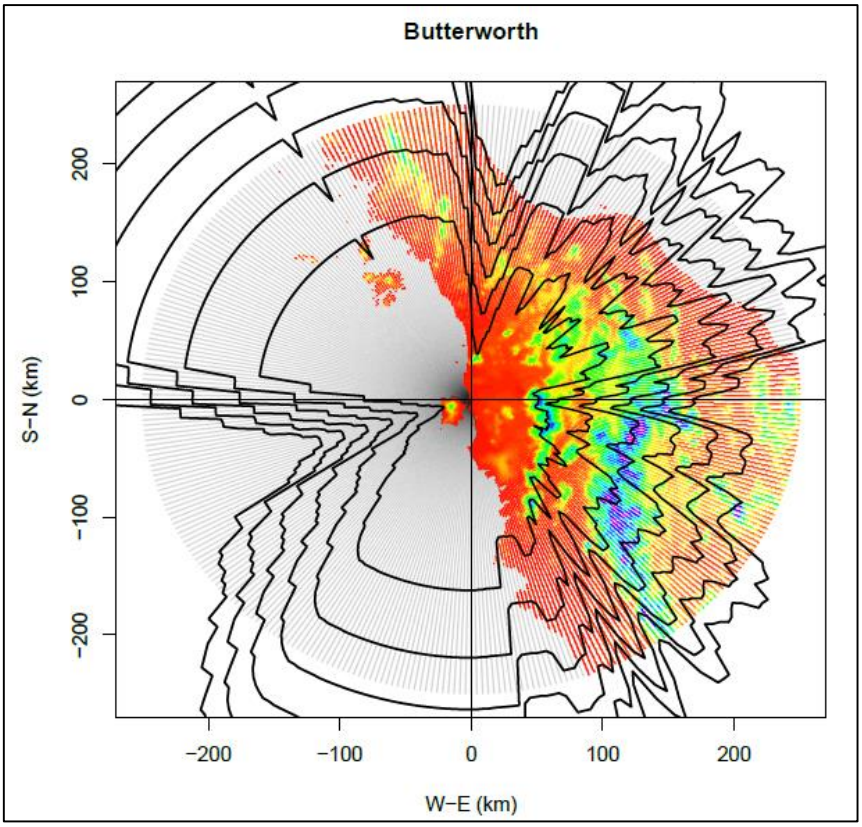


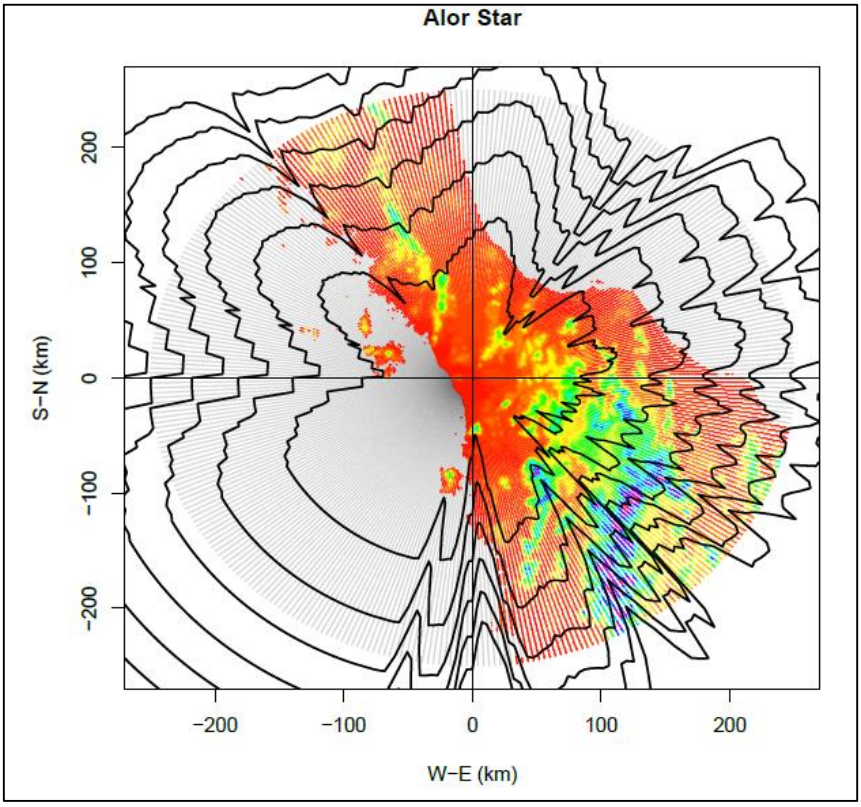


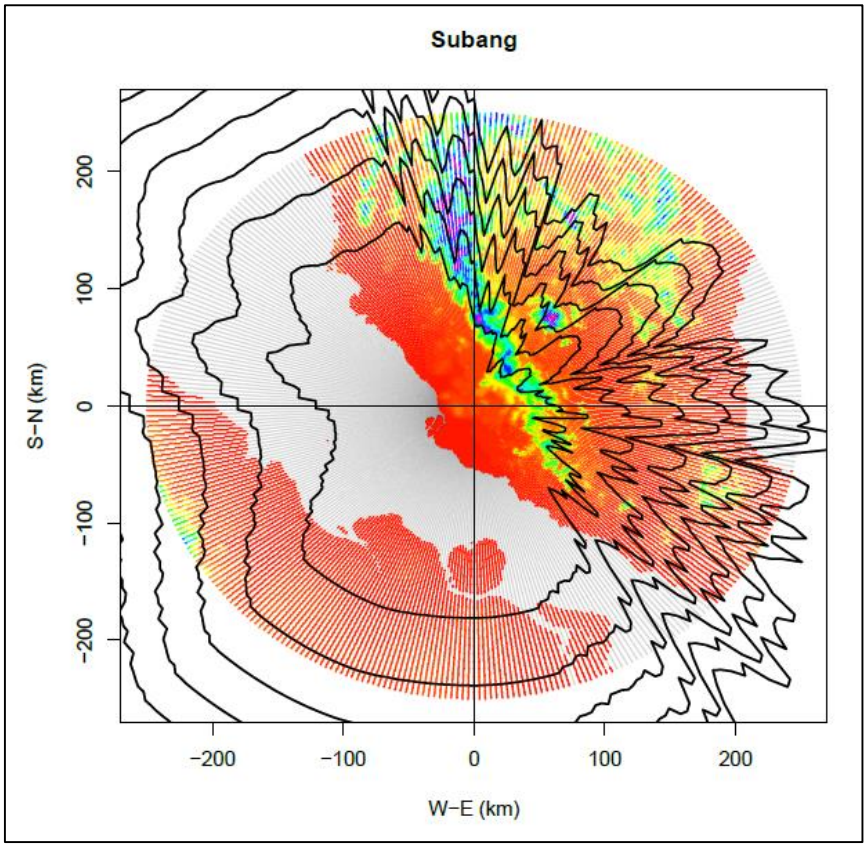

Butterworth
ag(deg)
4
2.2
1.2

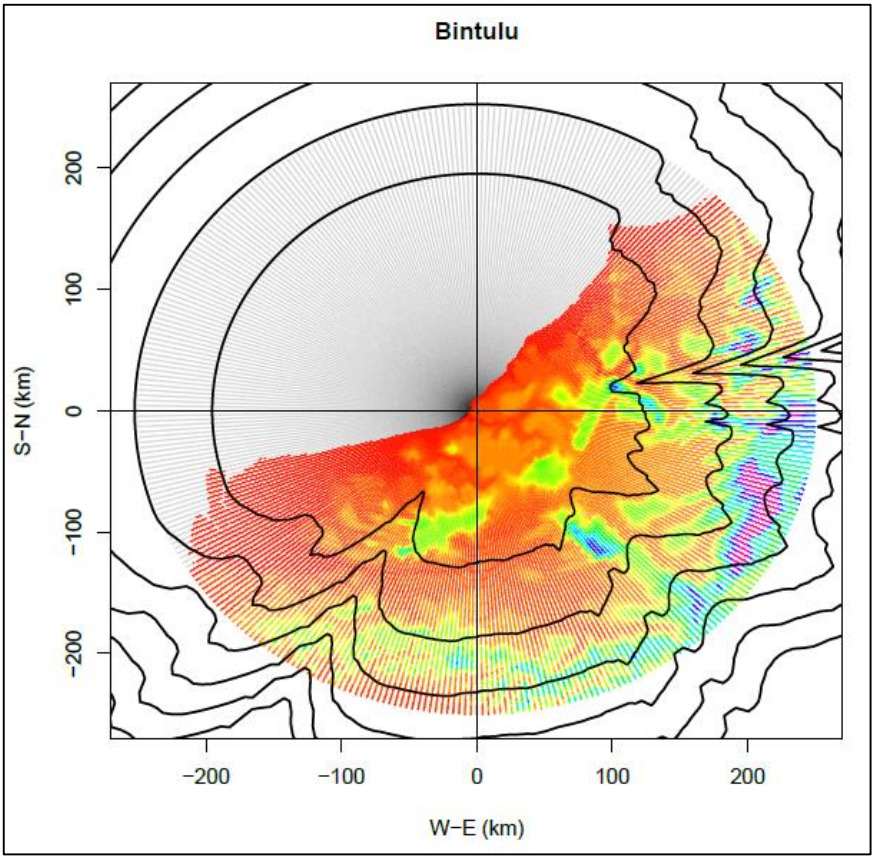

Subang
ag(deg)
2.5
1.5
0.7
0

Map of Topography Data






Subang
S–N (km)
200
100
0
−100
−200
−200
−100
0
100
200
W–E (km)


Bintulu
S–N (km)
200
100
0
−100
−200
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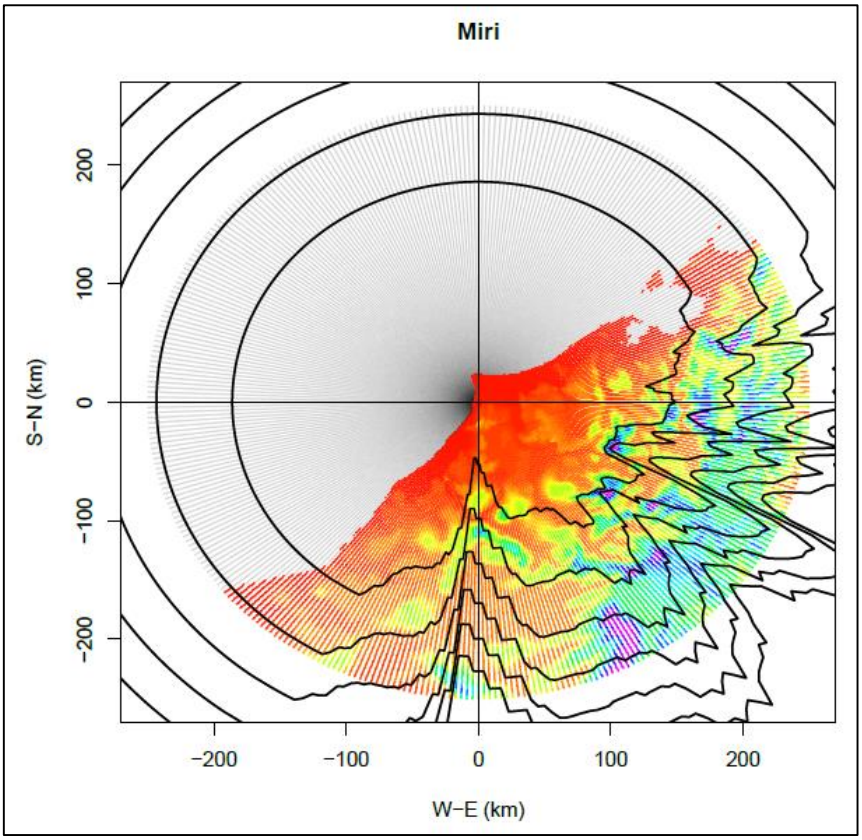
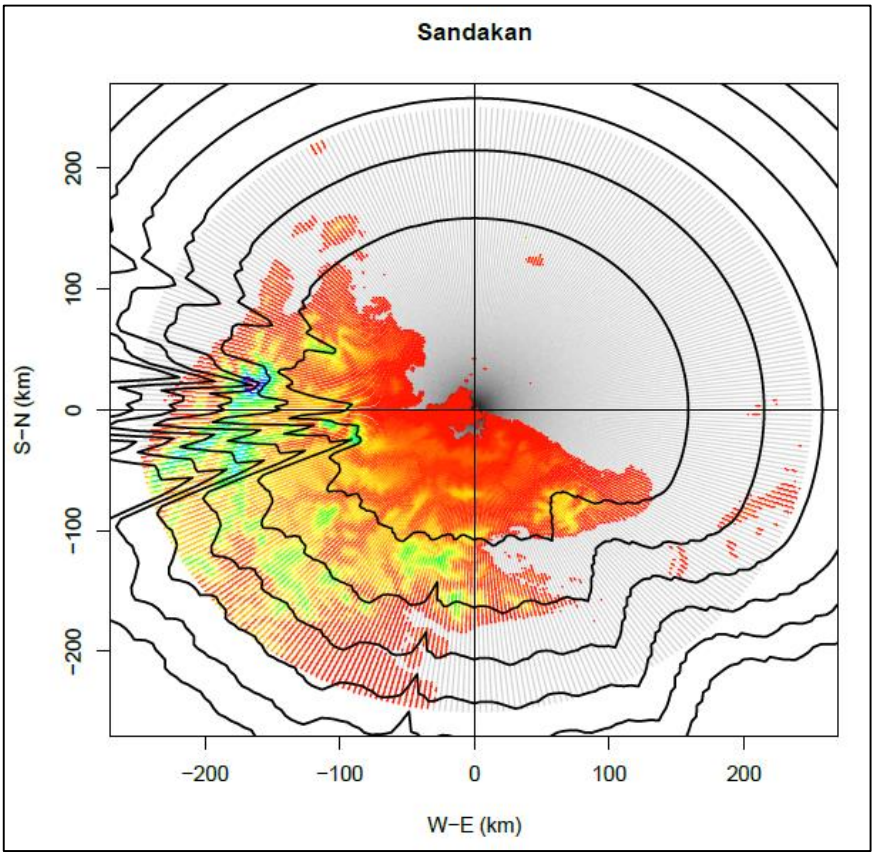
−100
0
100
200
W–E (km)


Miri
S−N (km)
W−E (km)
200
100
0
−100
−200
−200
−100
0
100
200


Sandakan
S−N (km)
W−E (km)
200
100
0
−100
−200
−200
−100
0
100
200