香港天文台
HONG KONG OBSERVATORY

Radar Applications in Tropical Cyclone and Extreme Weather Monitoring and Nowcasting Part II

Ray W Kong
Hong Kong Observatory, Hong Kong, China

TCRG Roving Seminar 2018
20-22 November 2018

香港天文台
HONG KONG OBSERVATORY

Content

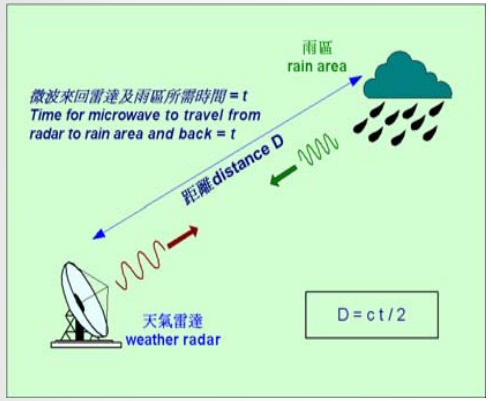
- Radar QPE
- Dual-polarization Weather Radar
- Interpretation of Extreme Weather on Radar Imagery
- Other Possible Scanning Strategy – 1-min Rapid Scan

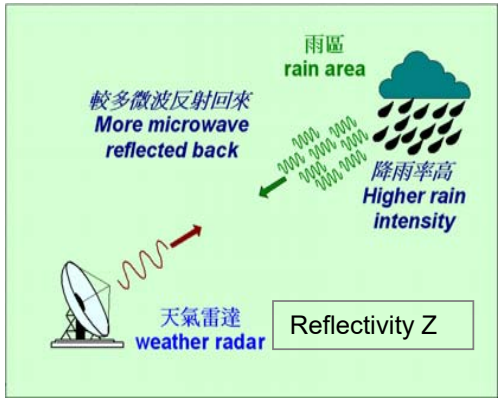
Content

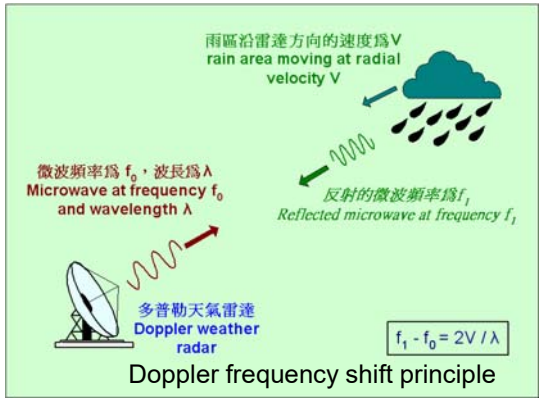
- Radar QPE
- Dual-polarization Weather Radar
- Interpretation of Extreme Weather on Radar Imagery
- Other Possible Scanning Strategy – 1-min Rapid Scan

香港天文台
HONG KONG OBSERVATORY

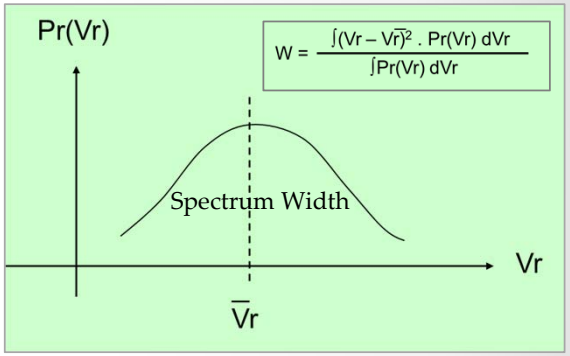
Single-polarization Weather Radar







Doppler frequency shift principle



Measure location, reflectivity (Z) , velocity (V) and spectrum width (W) of raindrops

Rainfall measurements

Reflectivity Z is related to the rainfall rate R by an empirical relation, Z-R relation:

$$Z = a R^b$$

For stratiform clouds, the relation is called Marshall-Palmer relation:

$$Z = 200 R^{1.6}$$

Image of Reflectivity (Z) of HKO radar

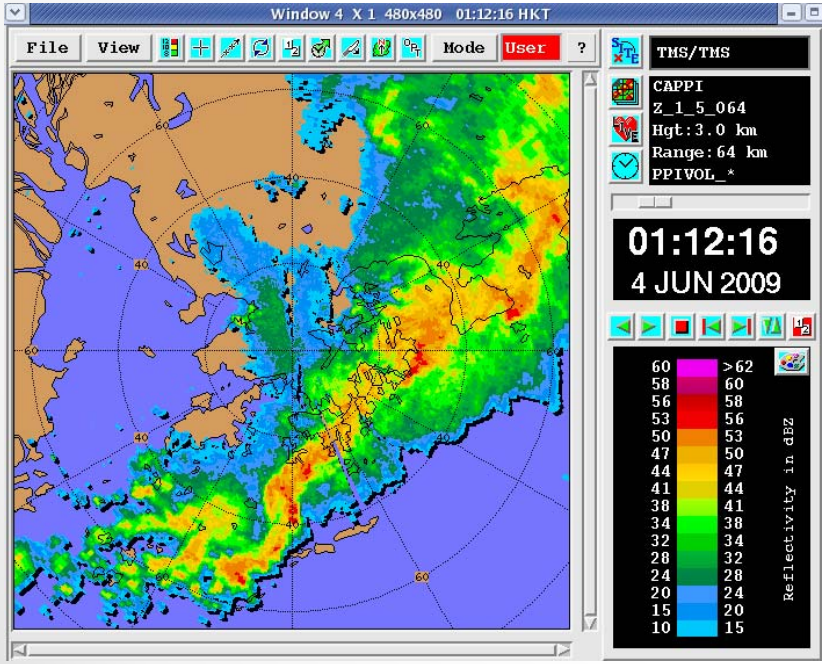
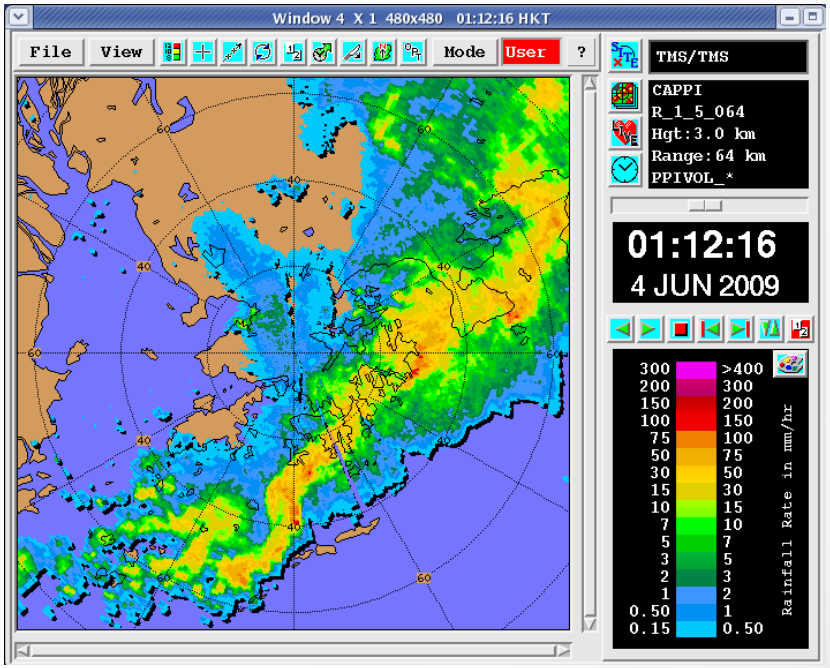
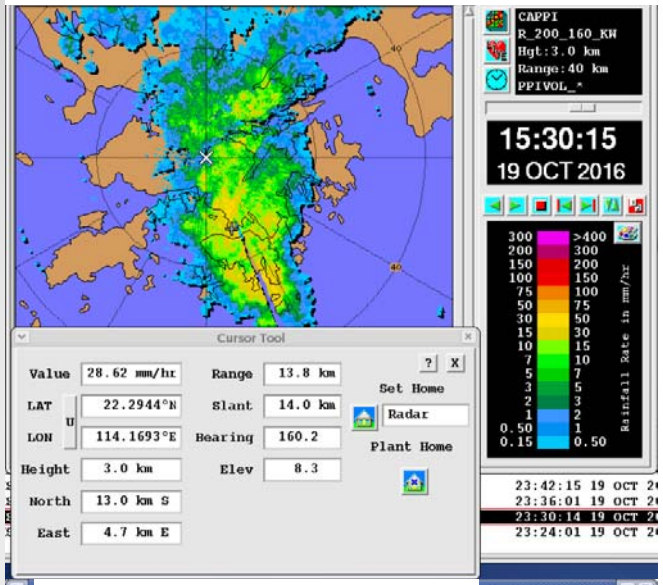


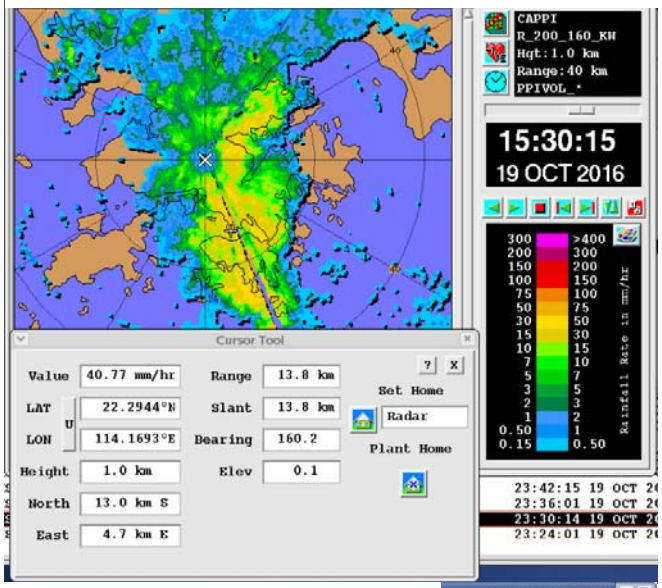
Image of Rainfall rate (R) of HKO radar using Marshall-Palmer relation



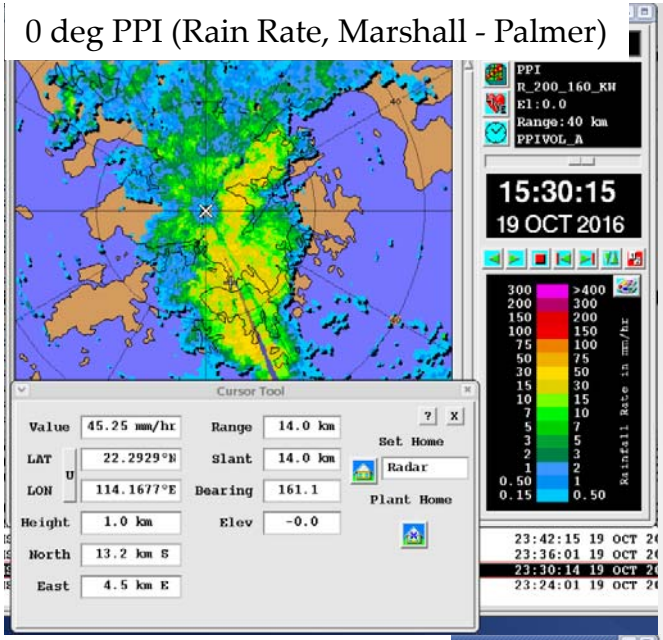
3 km CAPPI (Rain Rate, Marshall - Palmer)



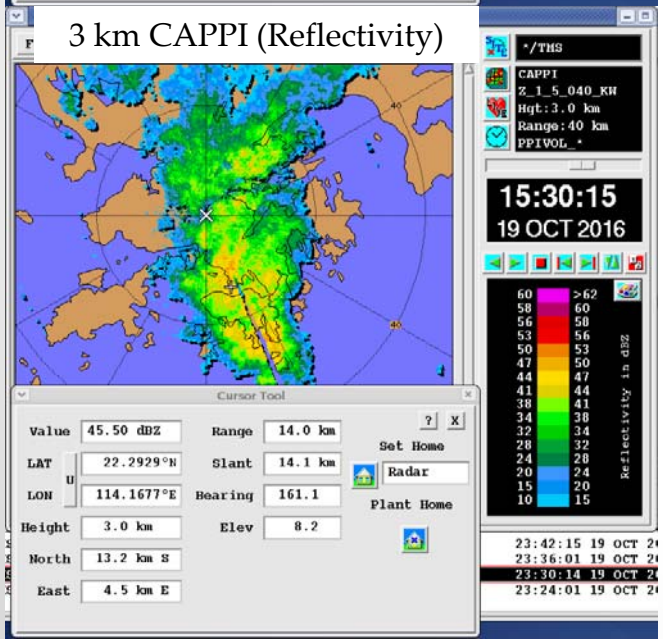
1 km CAPPI (Rain Rate, Marshall - Palmer)



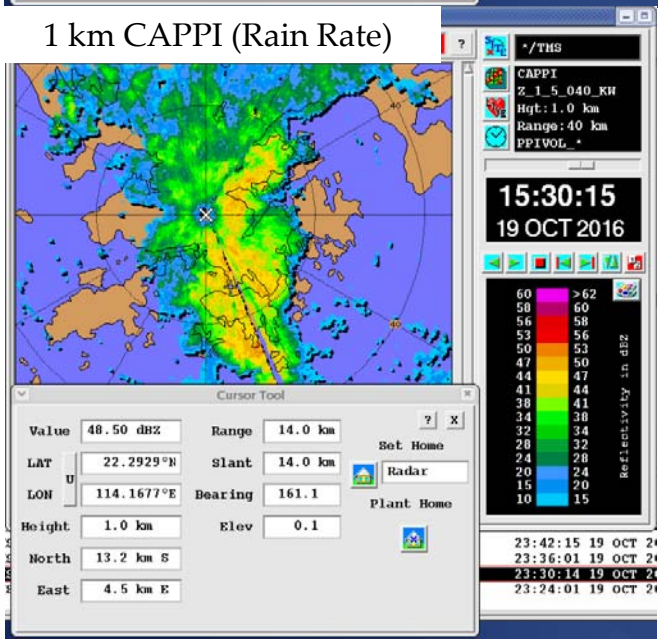
0 deg PPI (Rain Rate, Marshall - Palmer)



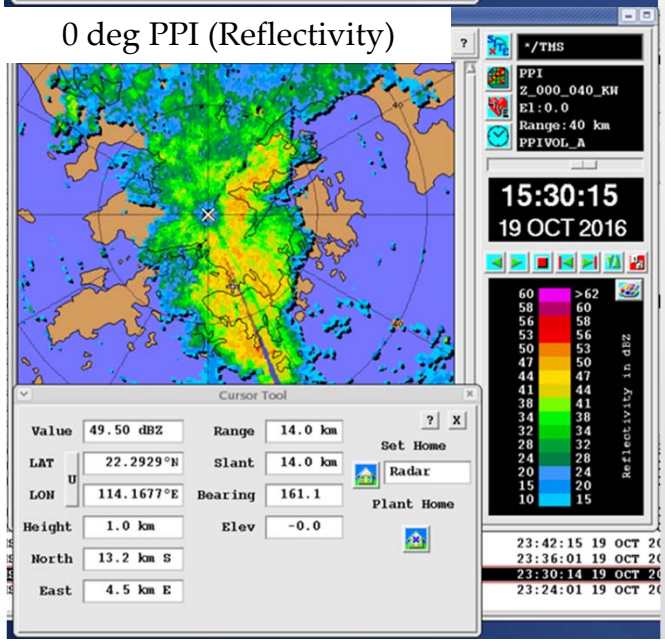
3 km CAPPI (Reflectivity)



1 km CAPPI (Rain Rate)



0 deg PPI (Reflectivity)

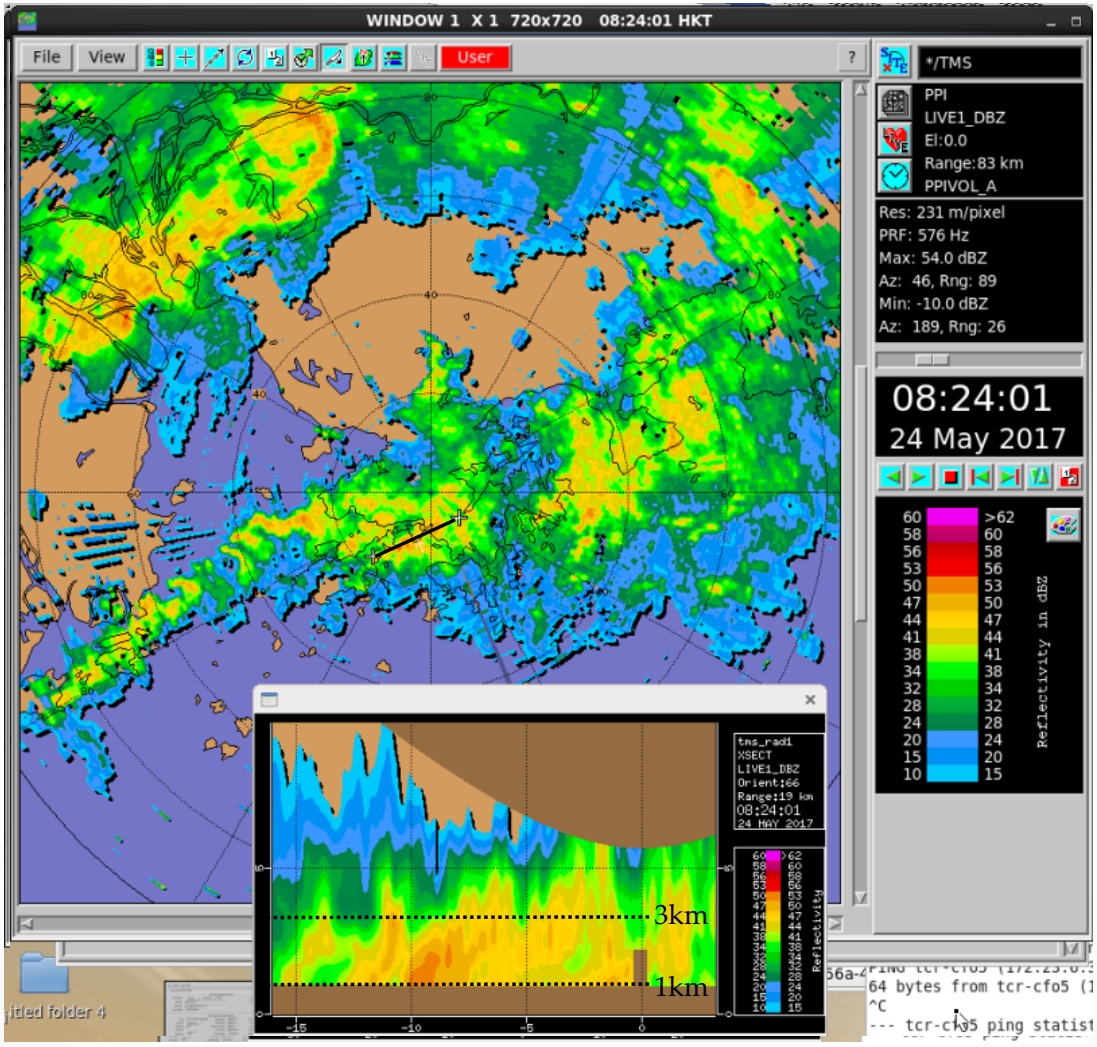


香港天文台
HONG KONG OBSERVATORY

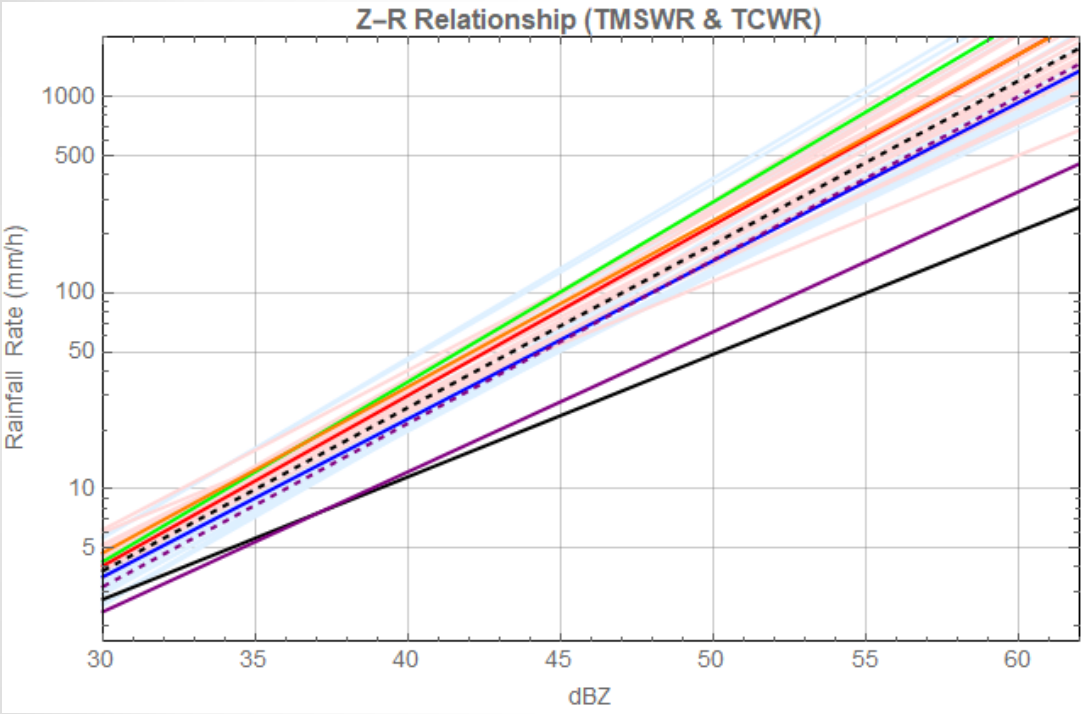
Recommendation

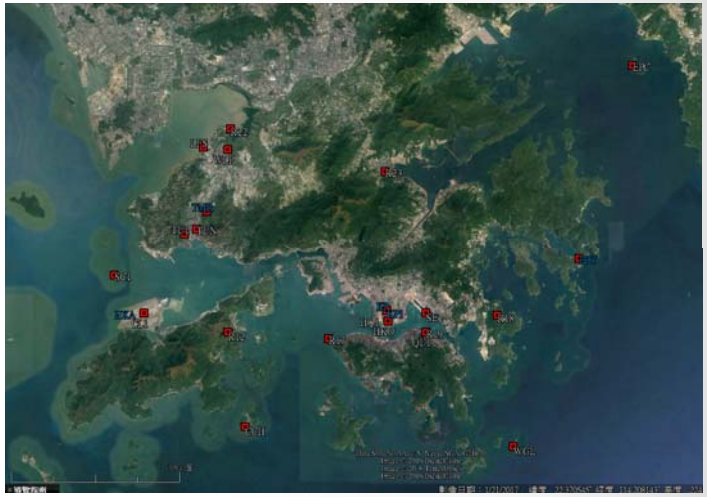
- Use of the lowest elevation PPI scan
- Why not CAPPI or higher elevation PPI scans?
  - Higher correlation with raingauges
  - Less latency time
    - 6 mins to complete a volume scan
    - Less than 1 min to complete the first and the lowest elevation scan
    - 5 mins advanced

Cross-section



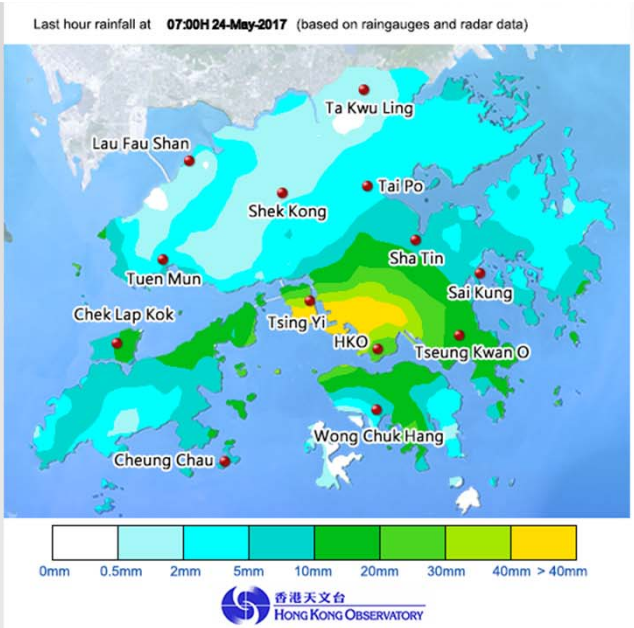
Z-R Relationship at the Lowest PPI Scan

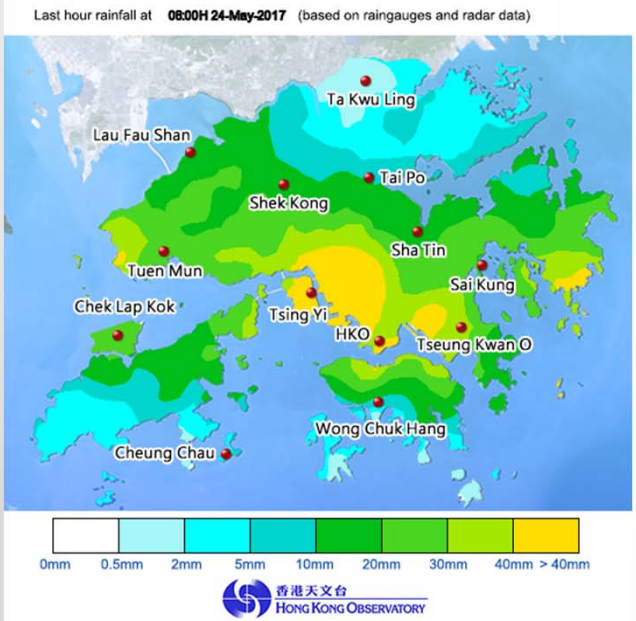


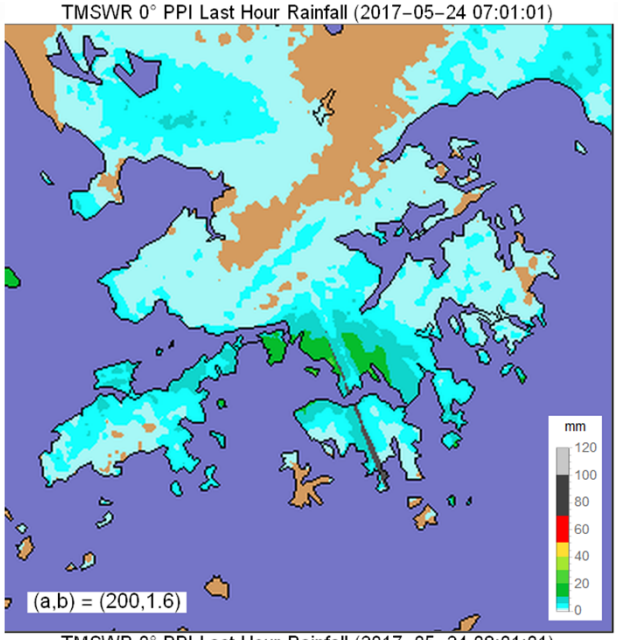


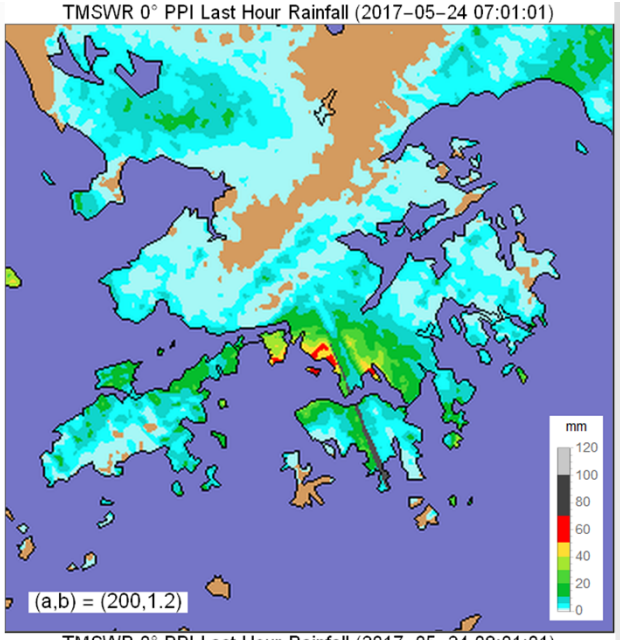
香港天文台
HONG KONG OBSERVATORY

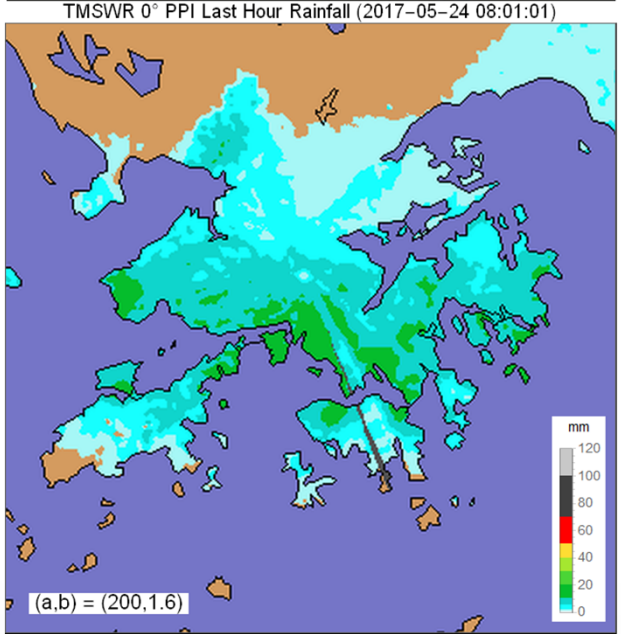
Example 1

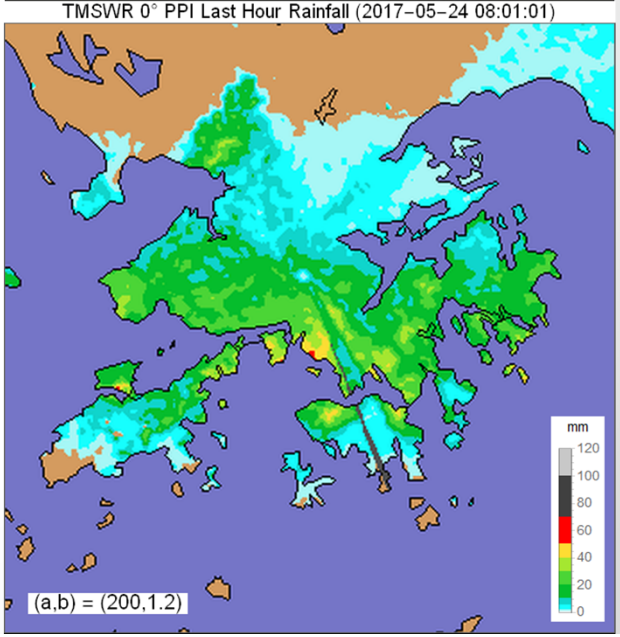

Last hour rainfall at 07:00H 24-May-2017 (based on raingauges and radar data)
Ta Kwu Ling
Lau Fau Shan
Tai Po
Shek Kong
Sha Tin
Tuen Mun
Sai Kung
Chek Lap Kok
Tsing Yi
HKO
Tseung Kwan O
Wong Chuk Hang
Cheung Chau
0mm 0.5mm 2mm 5mm 10mm 20mm 30mm 40mm > 40mm
香港天文台
Hong Kong Observatory

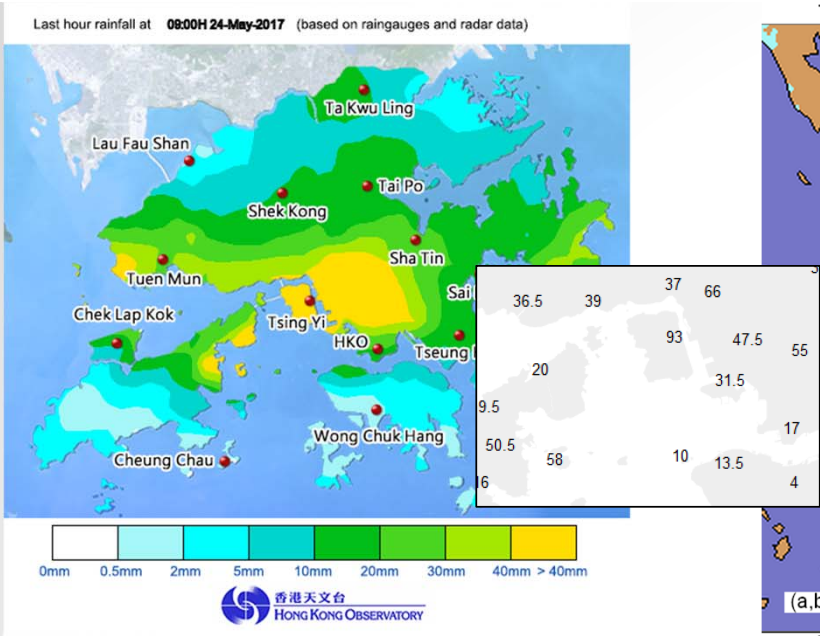

Last hour rainfall at 08:00H 24-May-2017 (based on raingauges and radar data)
Ta Kwu Ling
Lau Fau Shan
Tai Po
Shek Kong
Sha Tin
Tuen Mun
Sai Kung
Chek Lap Kok
Tsing Yi
HKO
Tseung Kwan O
Wong Chuk Hang
Cheung Chau
0mm 0.5mm 2mm 5mm 10mm 20mm 30mm 40mm > 40mm
香港天文台
Hong Kong Observatory

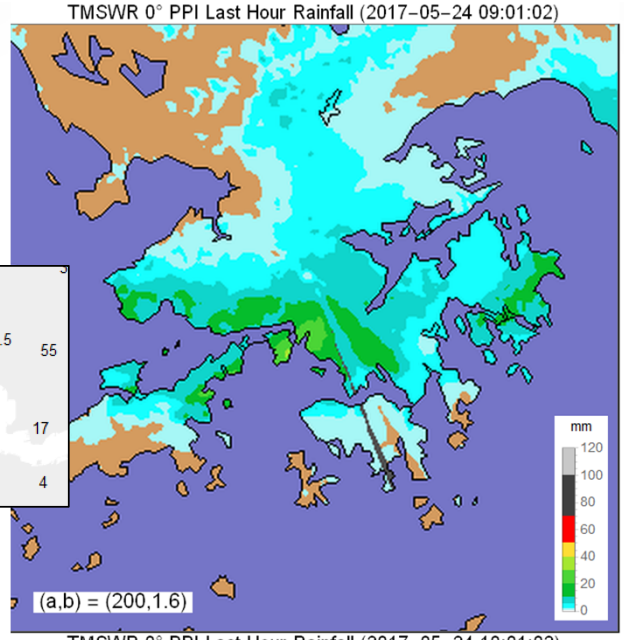

TMSWR 0° PPI Last Hour Rainfall (2017-05-24 07:01:01)
mm
120
100
80
60
40
20
0
(a,b) = (200,1.6)

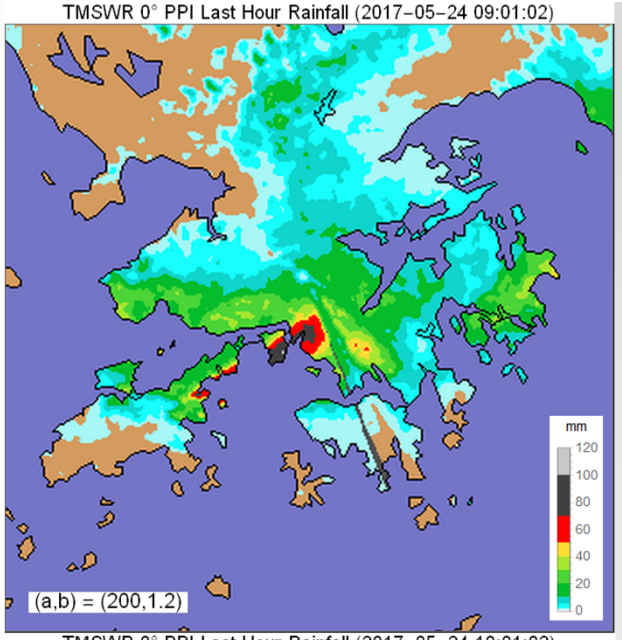

TMSWR 0° PPI Last Hour Rainfall (2017-05-24 07:01:01)
mm
120
100
80
60
40
20
0
(a,b) = (200,1.2)

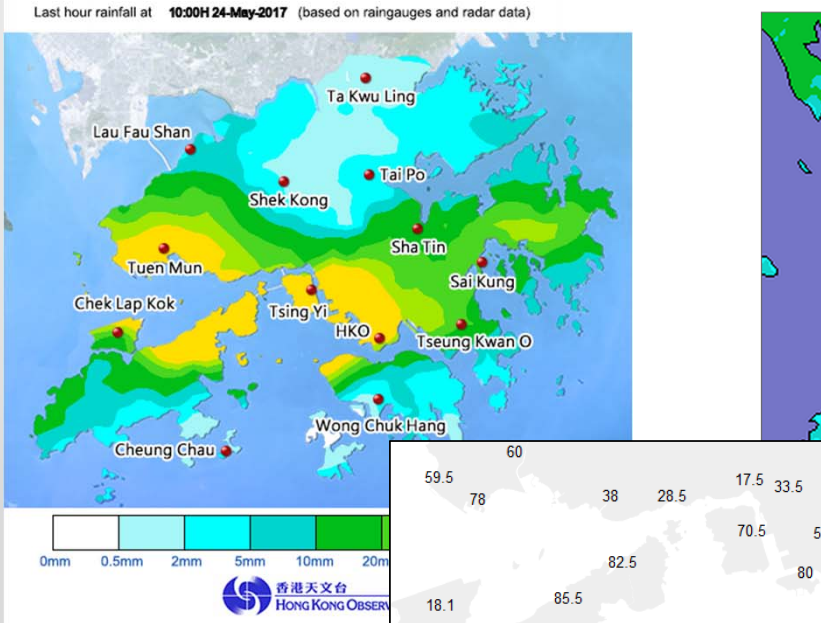

TMSWR 0° PPI Last Hour Rainfall (2017-05-24 08:01:01)
mm
120
100
80
60
40
20
0
(a,b) = (200,1.6)

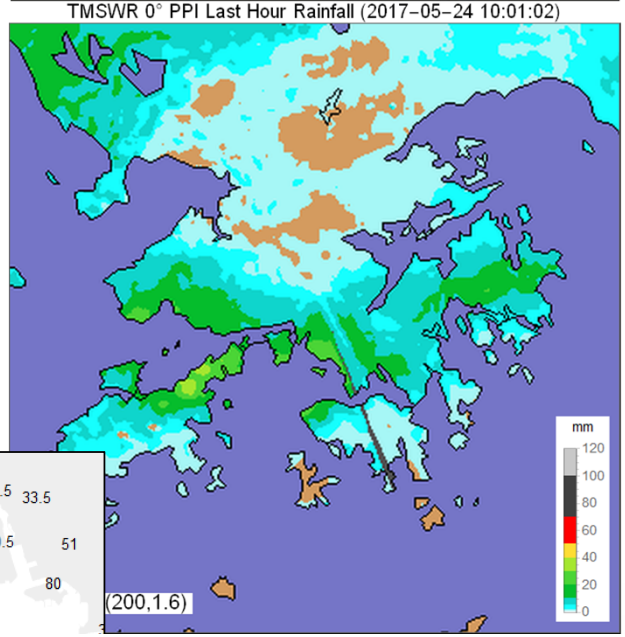

TMSWR 0° PPI Last Hour Rainfall (2017-05-24 08:01:01)
mm
120
100
80
60
40
20
0
(a,b) = (200,1.2)

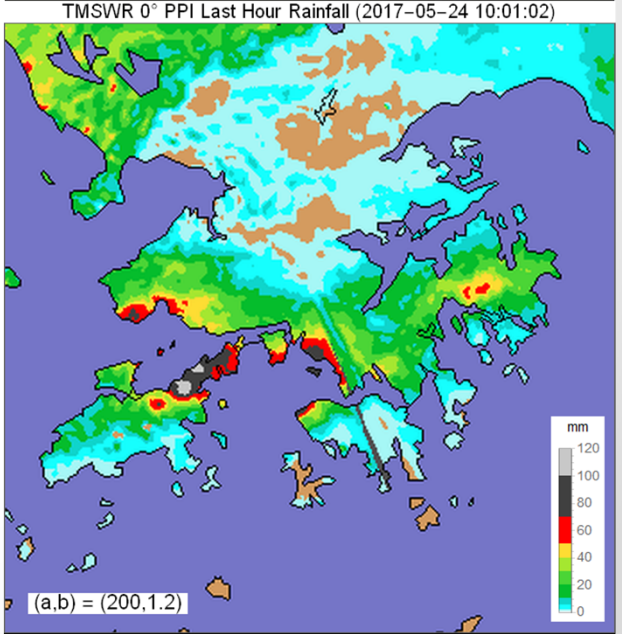

Last hour rainfall at 09:00H 24-May-2017 (based on raingauges and radar data)
Ta Kwu Ling
Lau Fau Shan
Tai Po
Shek Kong
Sha Tin
Tuen Mun
Sai
Chek Lap Kok
Tsing Yi
HKO
Tseung
Wong Chuk Hang
Cheung Chau
36.5
39
37
66
93
47.5
55
20
31.5
9.5
17
50.5
58
10
13.5
16
4
0mm
0.5mm
2mm
5mm
10mm
20mm
30mm
40mm
> 40mm
香港天文台
HONG KONG OBSERVATORY

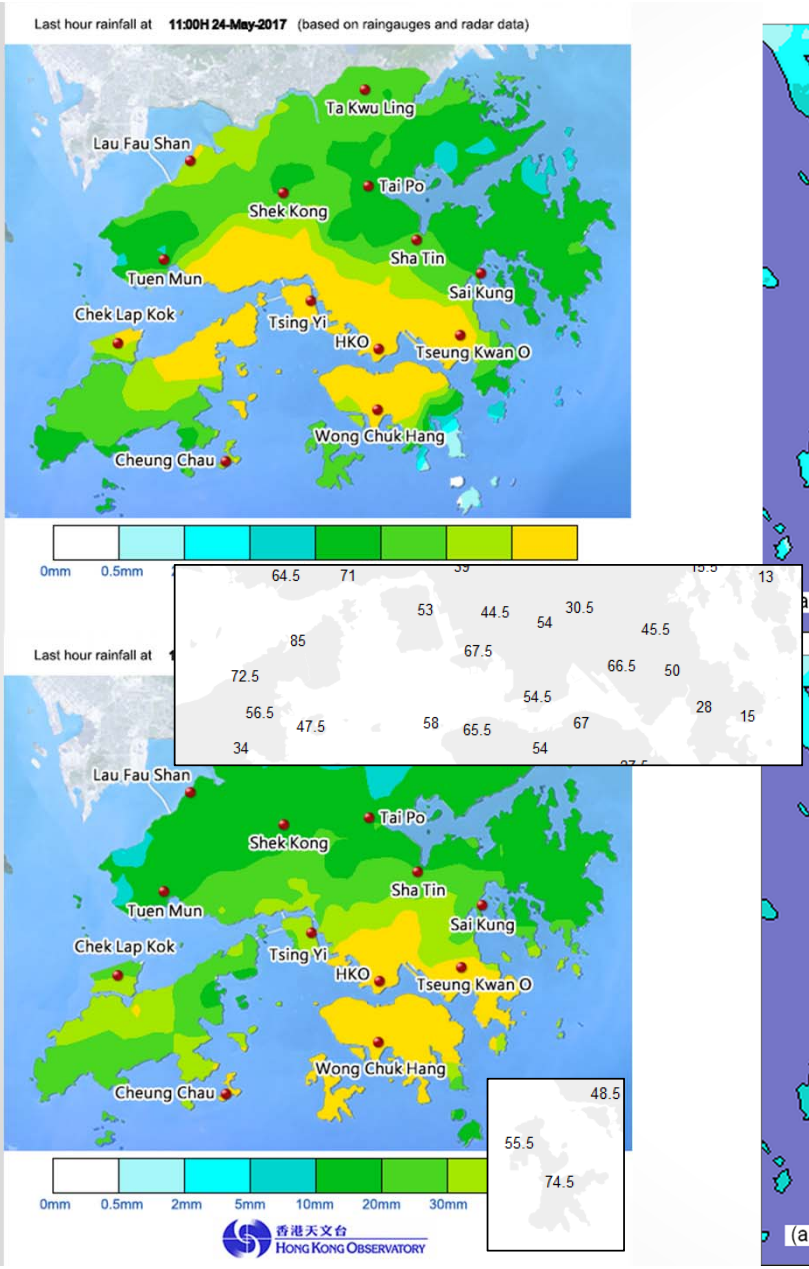

TMSWR 0° PPI Last Hour Rainfall (2017-05-24 09:01:02)
(a,b) = (200,1.6)
mm
120
100
80
60
40
20
0

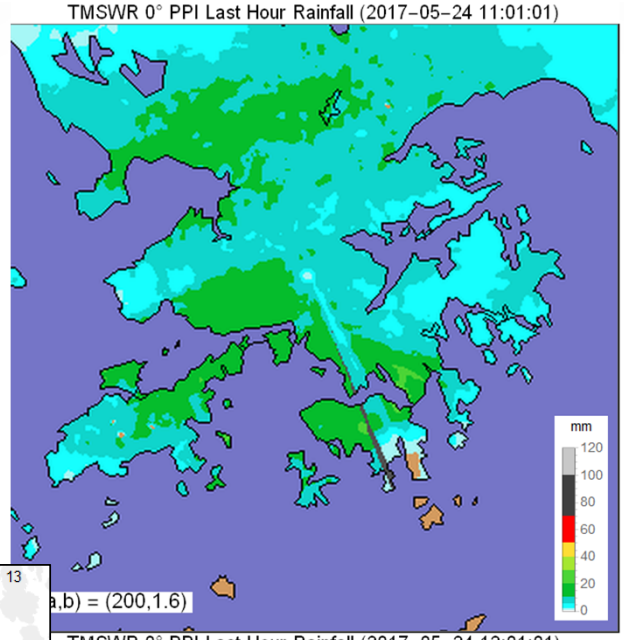

TMSWR 0° PPI Last Hour Rainfall (2017-05-24 09:01:02)
(a,b) = (200,1.2)
mm
120
100
80
60
40
20
0

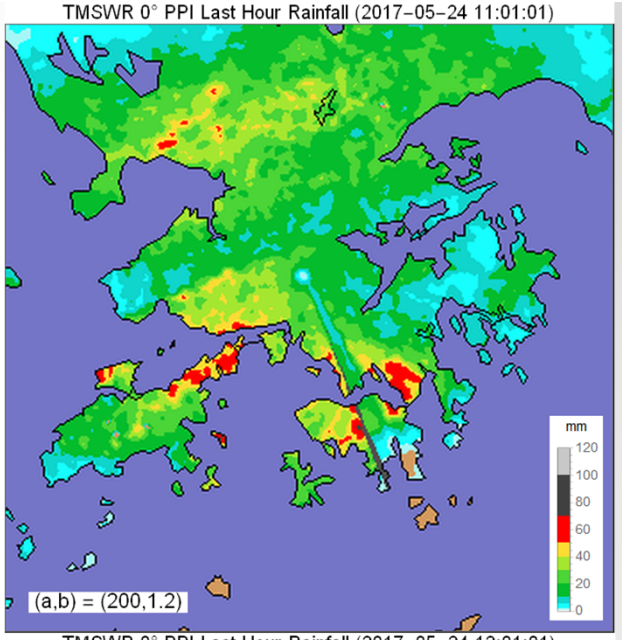

Last hour rainfall at 10:00H 24-May-2017 (based on raingauges and radar data)
Ta Kwu Ling
Lau Fau Shan
Tai Po
Shek Kong
Sha Tin
Tuen Mun
Sai Kung
Chek Lap Kok
Tsing Yi
HKO
Tseung Kwan O
Wong Chuk Hang
Cheung Chau
60
59.5
78
38
28.5
17.5
33.5
70.5
51
82.5
80
18.1
85.5
0mm
0.5mm
2mm
5mm
10mm
香港天文台

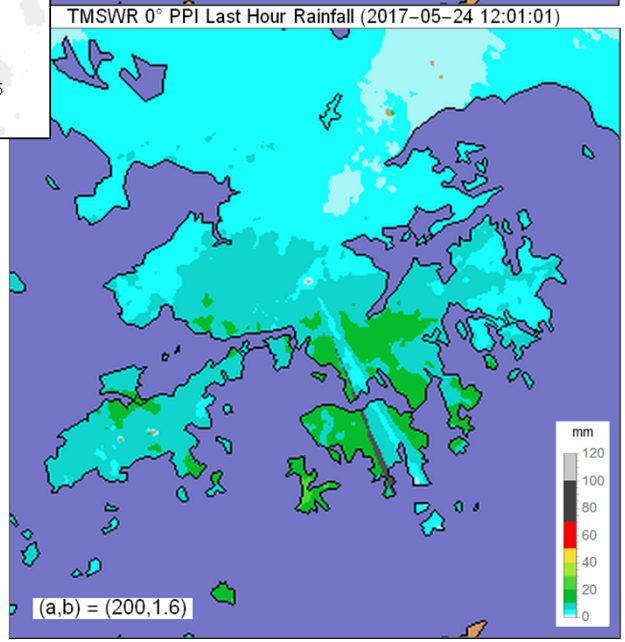

TMSWR 0° PPI Last Hour Rainfall (2017-05-24 10:01:02)
(200,1.6)
mm
120
100
80
60
40
20
0

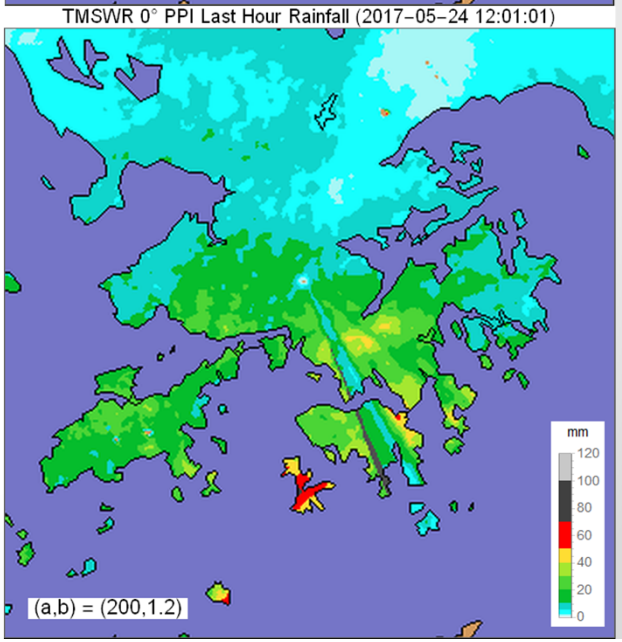

TMSWR 0° PPI Last Hour Rainfall (2017-05-24 10:01:02)
(a,b) = (200,1.2)
mm
120
100
80
60
40
20
0


Last hour rainfall at 11:00H 24-May-2017 (based on raingauges and radar data)
Ta Kwu Ling
Lau Fau Shan
Tai Po
Shek Kong
Sha Tin
Tuen Mun
Sai Kung
Chek Lap Kok
Tsing Yi
HKO
Tseung Kwan O
Wong Chuk Hang
Cheung Chau
0mm
0.5mm
2mm
5mm
10mm
20mm
30mm
64.5
71
53
44.5
54
30.5
45.5
85
67.5
66.5
50
72.5
54.5
56.5
47.5
58
65.5
67
28
15
34
54
13
48.5
55.5
74.5
香港天文台
Hong Kong Observatory

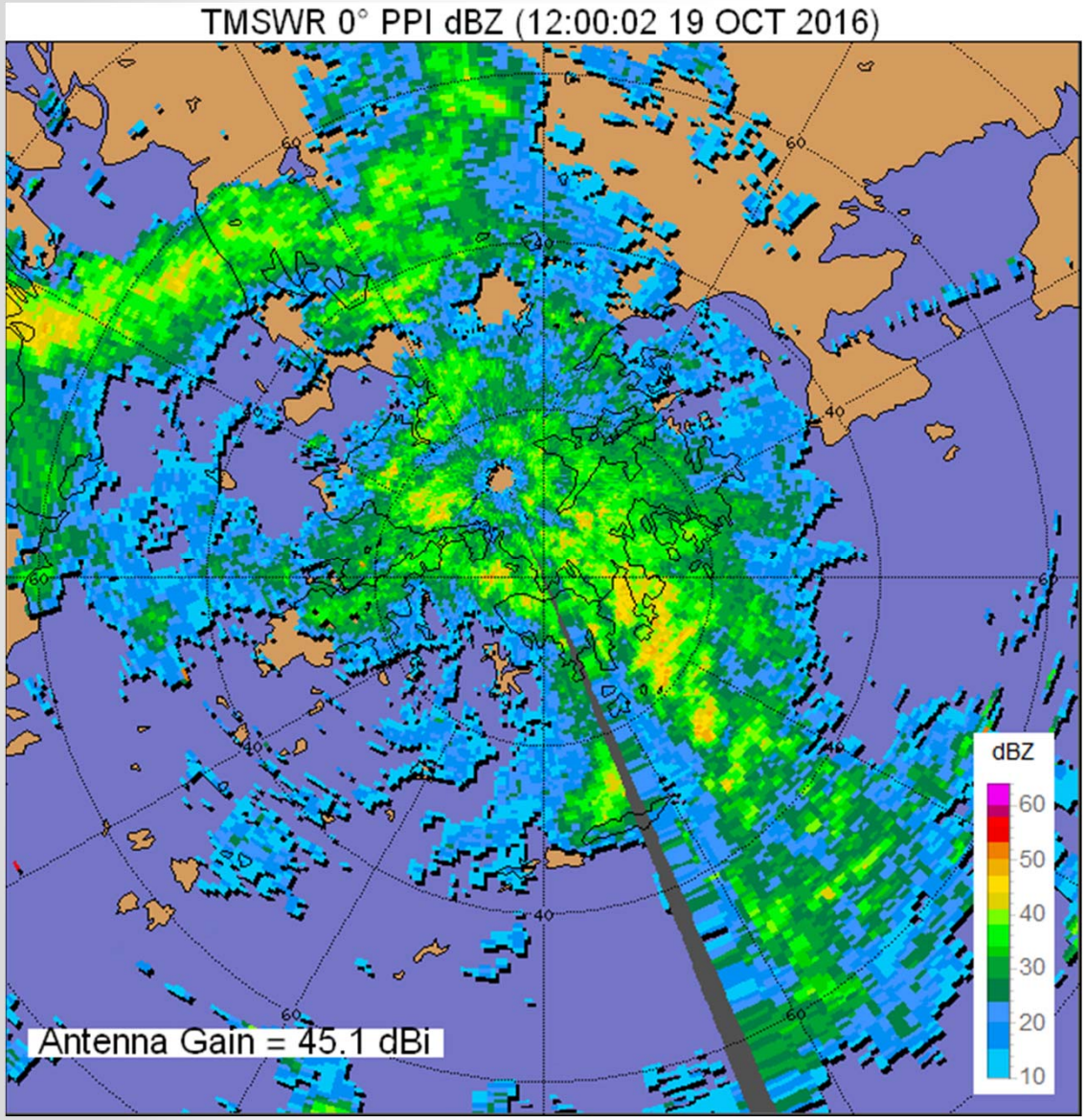

TMSWR 0° PPI Last Hour Rainfall (2017-05-24 11:01:01)
mm
120
100
80
60
40
20
0
(a,b) = (200,1.6)

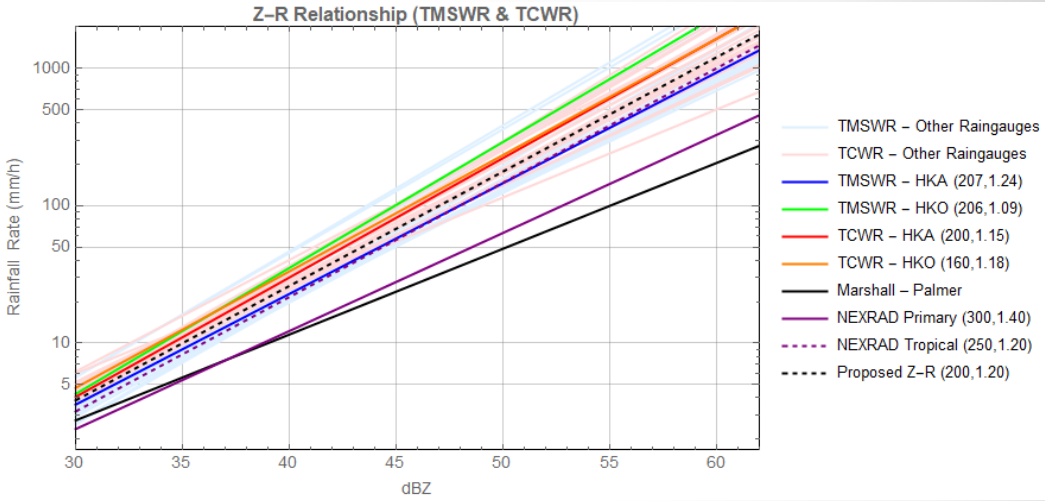

TMSWR 0° PPI Last Hour Rainfall (2017-05-24 11:01:01)
mm
120
100
80
60
40
20
0
(a,b) = (200,1.2)

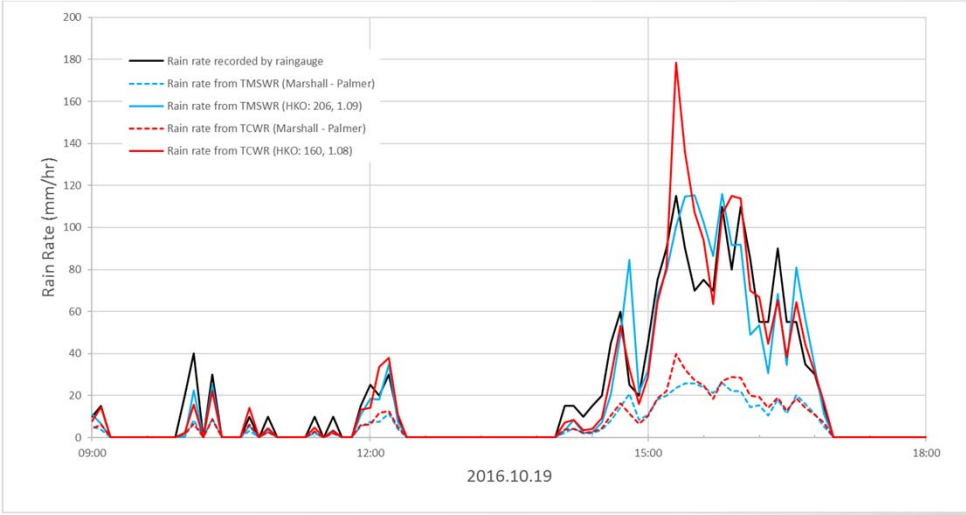

TMSWR 0° PPI Last Hour Rainfall (2017-05-24 12:01:01)
mm
120
100
80
60
40
20
0
(a,b) = (200,1.6)


TMSWR 0° PPI Last Hour Rainfall (2017-05-24 12:01:01)
mm
120
100
80
60
40
20
0
(a,b) = (200,1.2)

Example 2


TMSWR 0° PPI dBZ (12:00:02 19 OCT 2016)
dBZ
60
50
40
30
20
10
Antenna Gain = 45.1 dBi


Z–R Relationship (TMSWR & TCWR)
Rainfall Rate (mm/h)
1000
500
100
50
10
5
30
35
40
45
50
55
60
dBZ
TMSWR – Other Raingauges
TCWR – Other Raingauges
TMSWR – HKA (207,1.24)
TMSWR – HKO (206,1.09)
TCWR – HKA (200,1.15)
TCWR – HKO (160,1.18)
Marshall – Palmer
NEXRAD Primary (300,1.40)
NEXRAD Tropical (250,1.20)
Proposed Z–R (200,1.20)

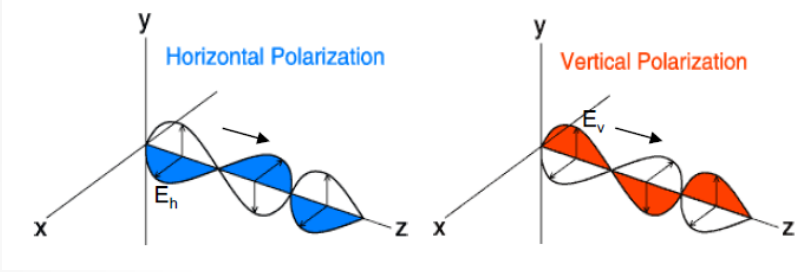

Rain rate recorded by raingauge
Rain rate from TMSWR (Marshall - Palmer)
Rain rate from TMSWR (HKO: 206, 1.09)
Rain rate from TCWR (Marshall - Palmer)
Rain rate from TCWR (HKO: 160, 1.08)
Rain Rate (mm/hr)
200
180
160
140
120
100
80
60
40
20
0
09:00
12:00
15:00
18:00
2016.10.19

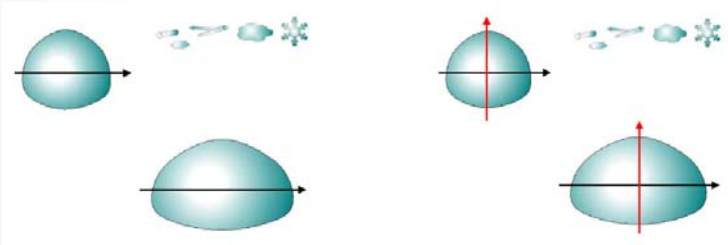
Content

- Radar QPE
- Dual-polarization Weather Radar
- Interpretation of Extreme Weather on Radar Imagery
- Other Possible Scanning Strategy – 1-min Rapid Scan

Dual-polarization Radar

- Dual-polarization radar transmit and receive both horizontal and vertical polarized pulses.





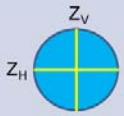
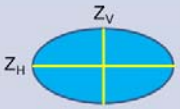
Single-polarization Dual-polarization

Raw Data

- Reflectivity (*Z*)
- Velocity (*V*)
- Spectral Width (*W*)
- Differential Reflectivity (*ZDR*)
- Differential Phase (Φ_{DP})
- Specific Differential Phase (K_{DP})
- Correlation Coefficient (ρ_{hv})

Differential Reflectivity (ZDR)

- Good indicator of the mean drop shape of the dominant hydrometeor within the resolution volume

Spherical (drizzle, small hail, etc.)	Horizontally Oriented (rain, melting hail, etc.)	Vertically Oriented (i.e. vertically oriented ice crystals)
		
$Z_H \sim Z_V$	$Z_H > Z_V$	$Z_H < Z_V$
$Z_H - Z_V \sim 0$	$Z_H - Z_V > 0$	$Z_H - Z_V < 0$
ZDR ~ 0 dB	ZDR > 0 dB	ZDR < 0 dB

- Rain ->
- Hail tends to tumble
  - appears spherical to radar
  - ZDR ~ 0 dB
- Small and completely water-coated hail
  - appears as giant raindrop
  - ZDR ~ 5-6 dB
- Non-met echoes
  - Ground clutter: very noisy
  - Biological scatterers: less noisy, orientation with flight direction

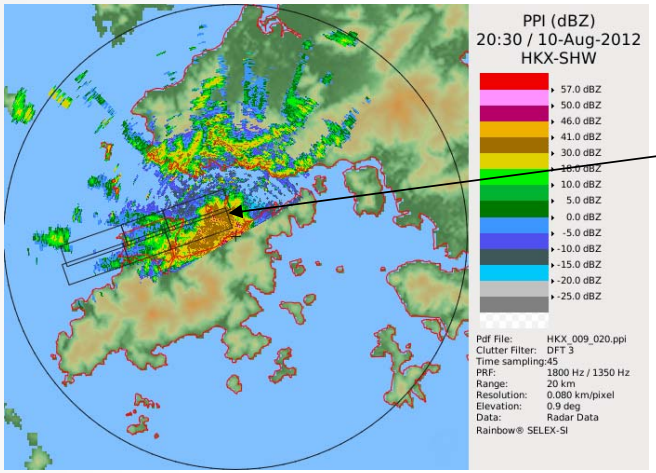
Major Axis Diameter (mm)	Image	ZDR (dB)
< 0.3 mm		~ 0.0 dB
1.35 mm		~ 1.3 dB
1.75 mm		~1.9 dB
2.65 mm		~2.8 dB
2.90 mm		~3.3 dB
3.68 mm		~4.1 dB
4.00 mm		~4.5 dB

Data from Wakimoto and Bringi (1988)

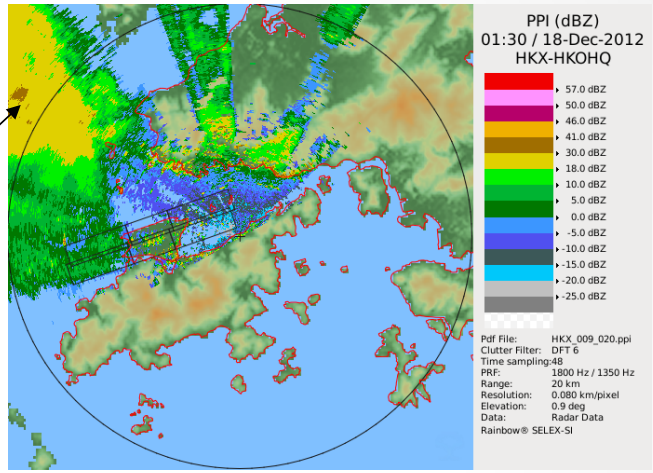
Physical interpretation of ZDR for raindrop

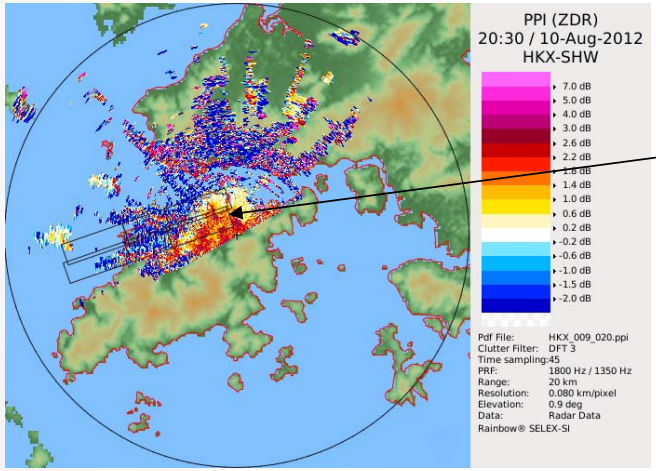
香港天文台
HONG KONG OBSERVATORY

Example

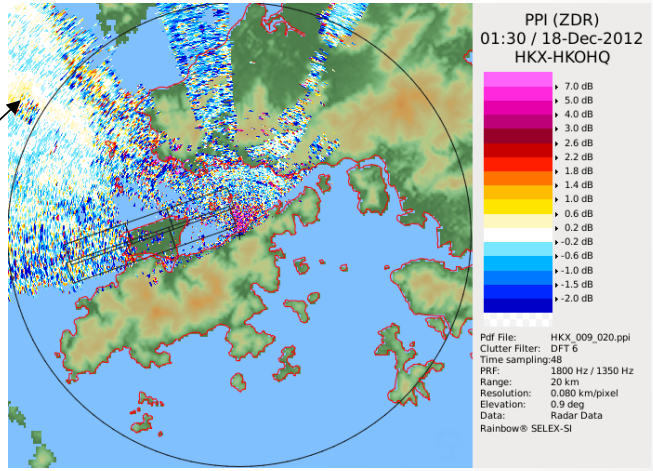


Similar Reflectivity





Very different in ZDR

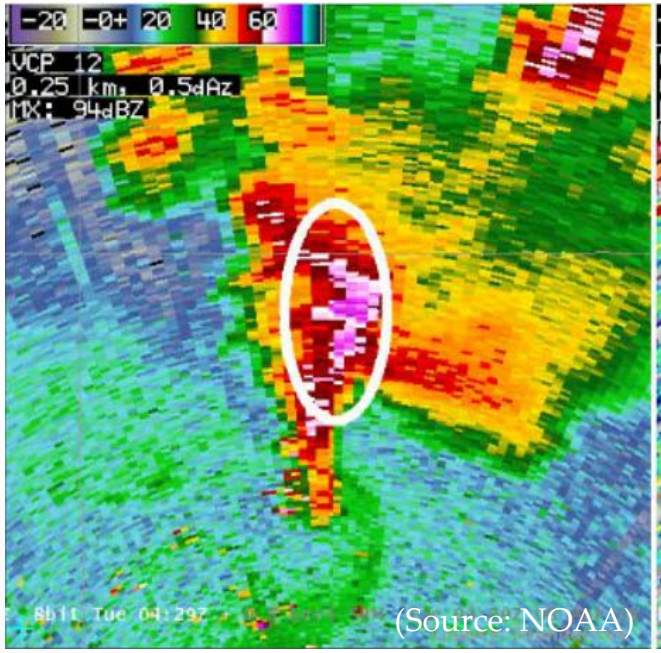


Showers by active SW'lies

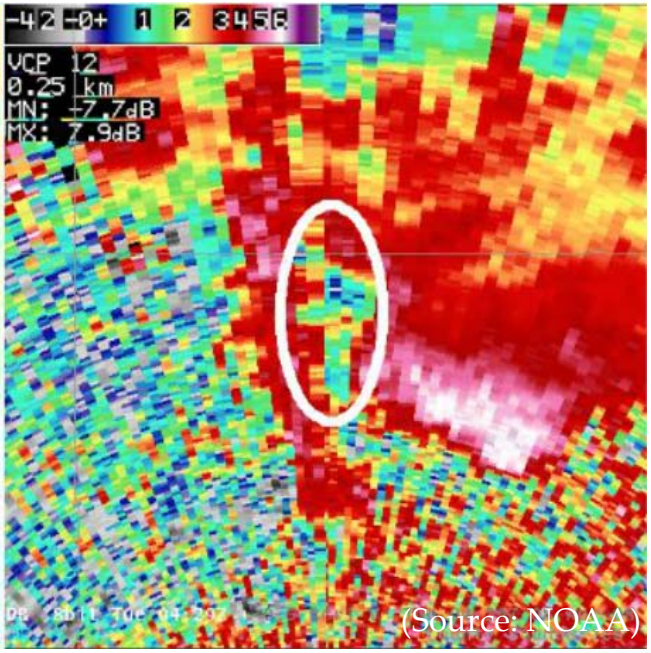
Stratiform Rain by undercutting

ZDR

- Large DBZ, but Zdr is small hail – A good detector of hail



(Source: NOAA)



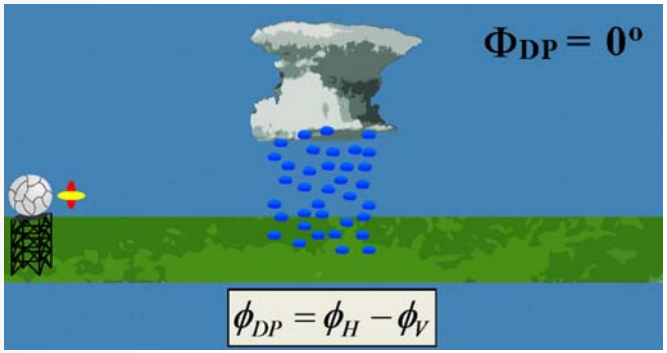
(Source: NOAA)

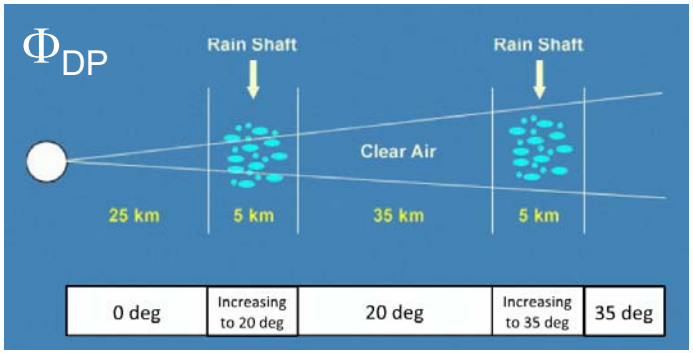
$$Z \propto D^6$$

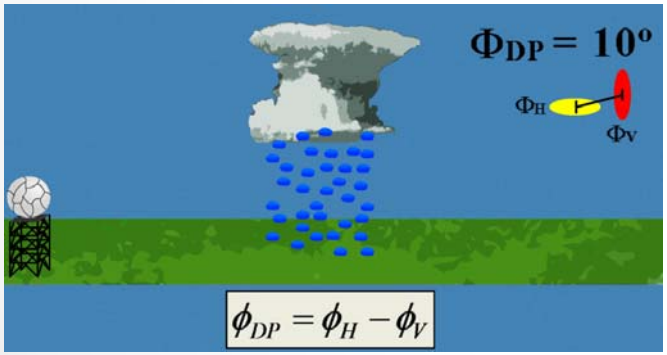
香港天文台
HONG KONG OBSERVATORY

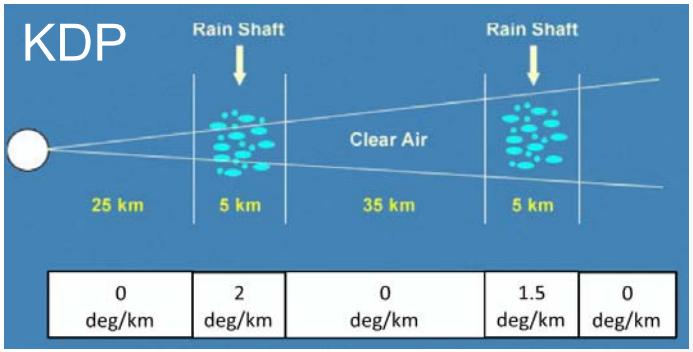
Differential Phase (Φ_{DP}) & Specific Differential Phase (KDP)

- Horizontal and vertical pulses slow down through medium
- If the target is not a perfect sphere, differential phase shift (Φ_{DP}) / specific differential phase (KDP) is resulted



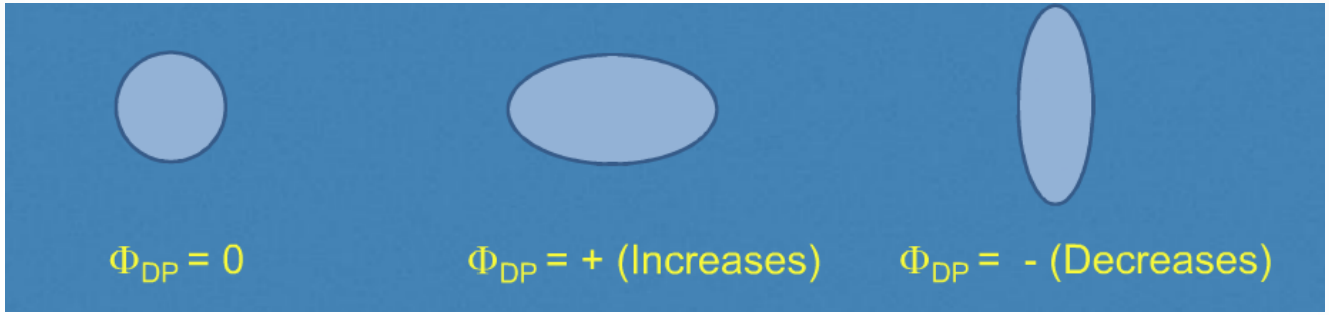




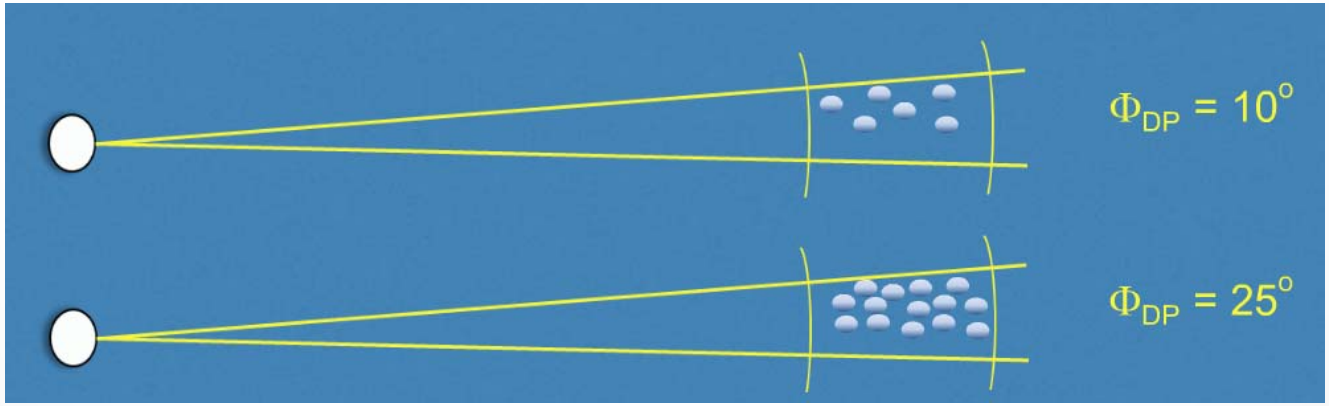


Interpretation of Φ_{DP} / KDP

- Shape



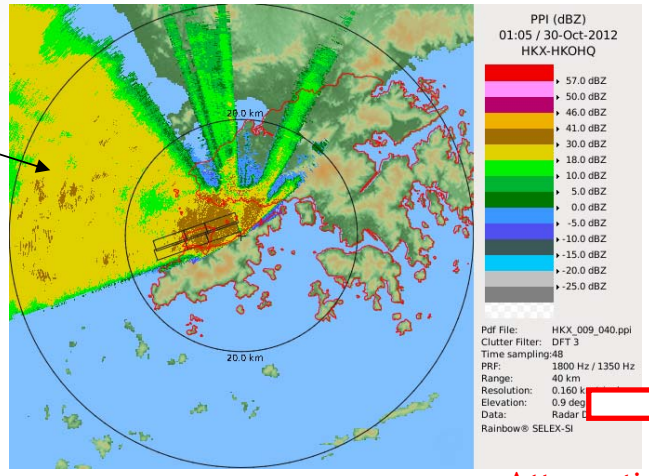
- Particle Concentration

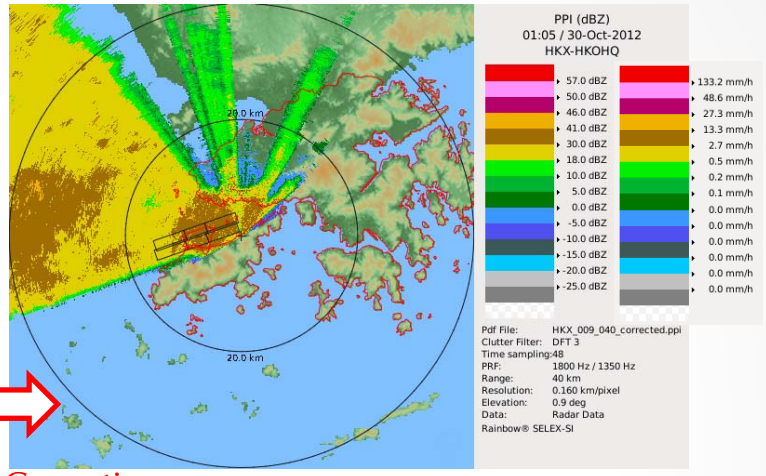


香港天文台
HONG KONG OBSERVATORY

Example 3

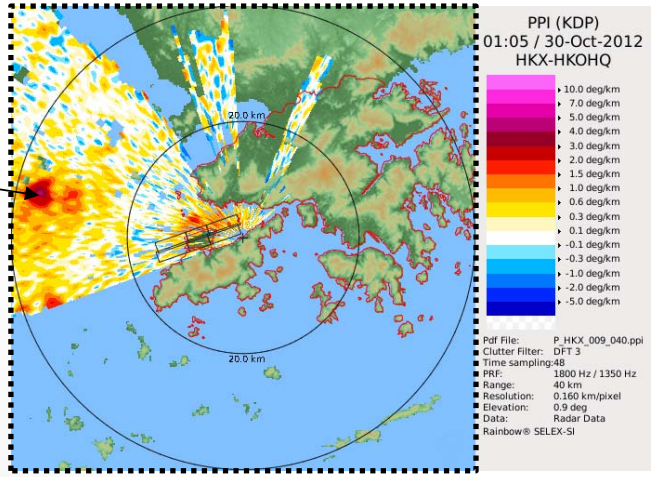
Uniform Rain Rate

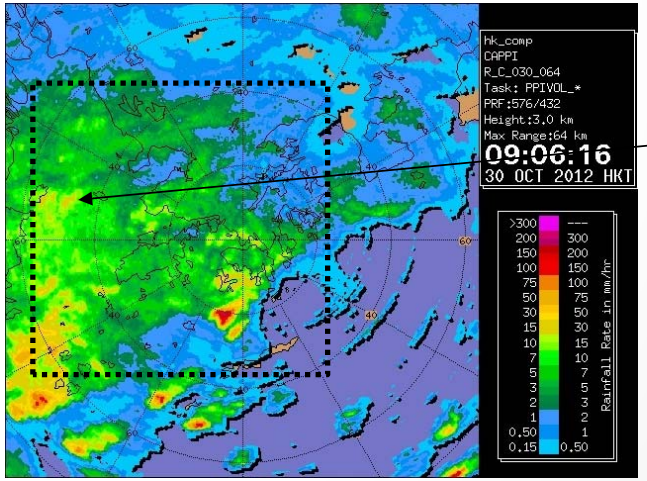




Attenuation Correction

Higher KDP, Higher Rain Rate



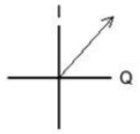
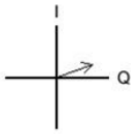
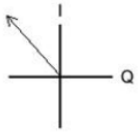
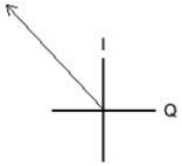
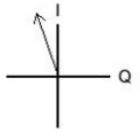


Higher Rain Rate in TMSWR

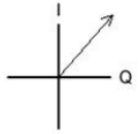
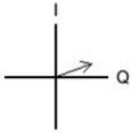
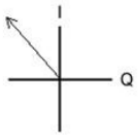
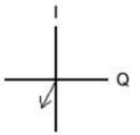
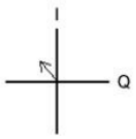
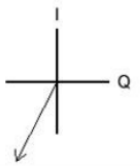
Correlation Coefficient (ρ_{hv})

- Definition
  - Measure of how similarly the horizontally and vertically polarized pulses are behaving within a pulse volume.

High Correlation Coefficient

Pulse #	Horizontal	Vertical
1		
2		
3		

Low Correlation Coefficient

Pulse #	Horizontal	Vertical
1		
2		
3		

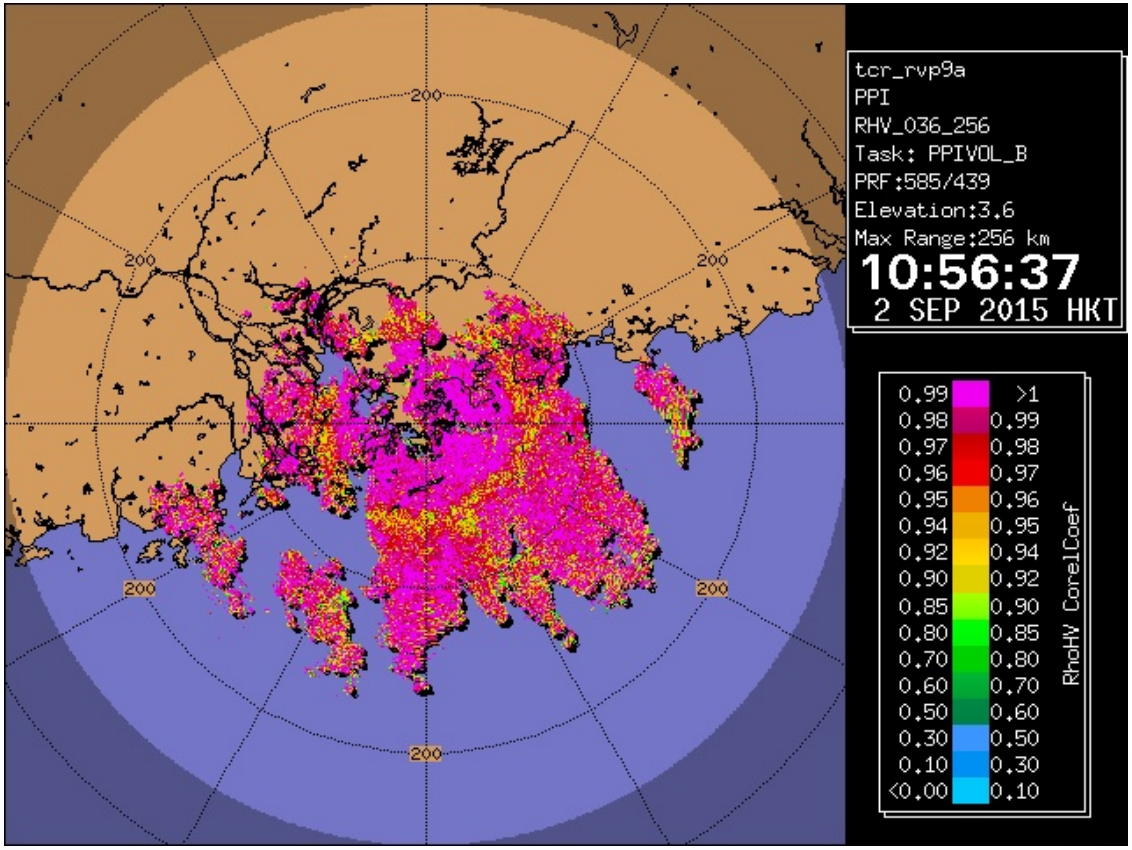
香港天文台
HONG KONG OBSERVATORY

Correlation Coefficient (ρ_{hv})

- Measure of how similarly the horizontally and vertically polarized pulses are behaving within a pulse volume.

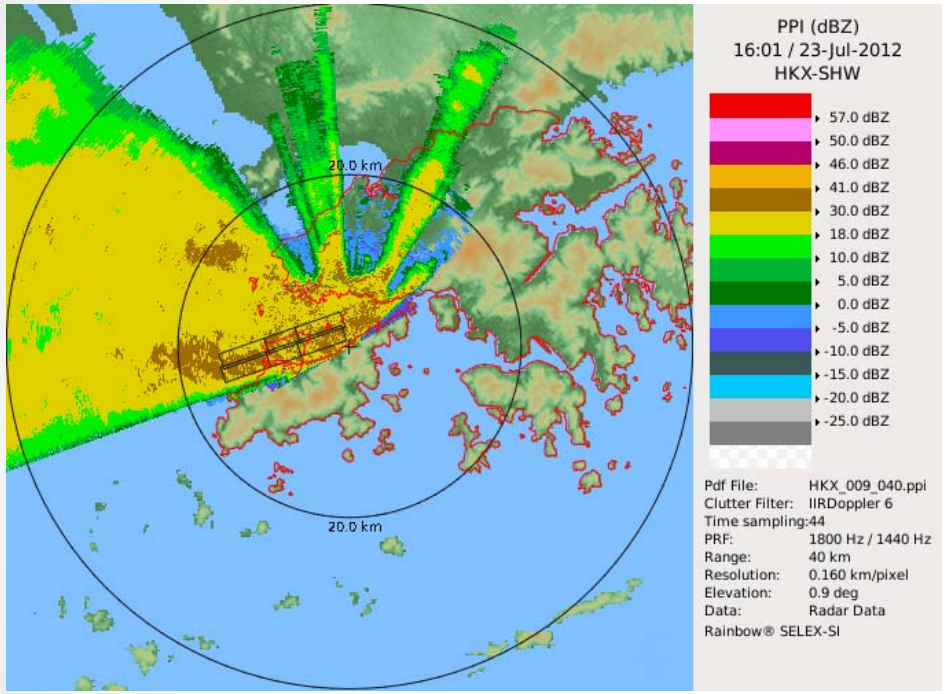
Non-Meteorological (birds, insects, etc.)	Metr (Non-Uniform) (hail, melting snow, etc.)	Metr (Uniform) (rain, snow, etc.)
		
Complex scattering from pulse-to-pulse. Horizontal and vertical pulses change in different manners from pulse-to-pulse	Somewhat complex scattering from pulse-to-pulse. Moderate differences from pulse-to-pulse for the horizontal and vertical pulses	Well-behaved scattering from pulse-to-pulse. Little differences from pulse-to-pulse for the horizontal and vertical pulses
Low CC (< 0.8)	Moderate CC (0.80 to 0.97)	High CC (> 0.97)

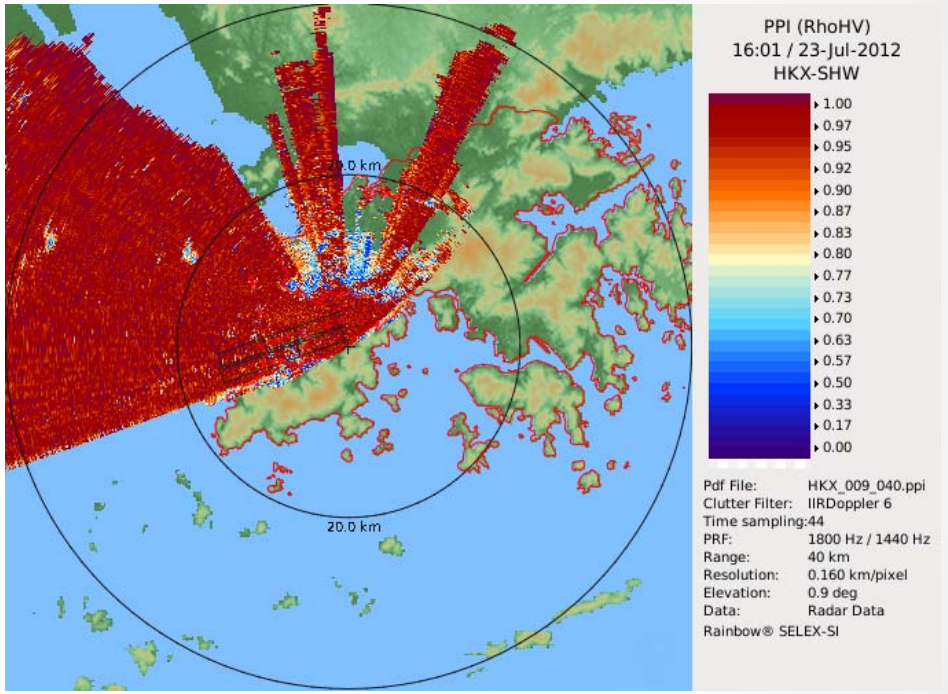
Melting Layer



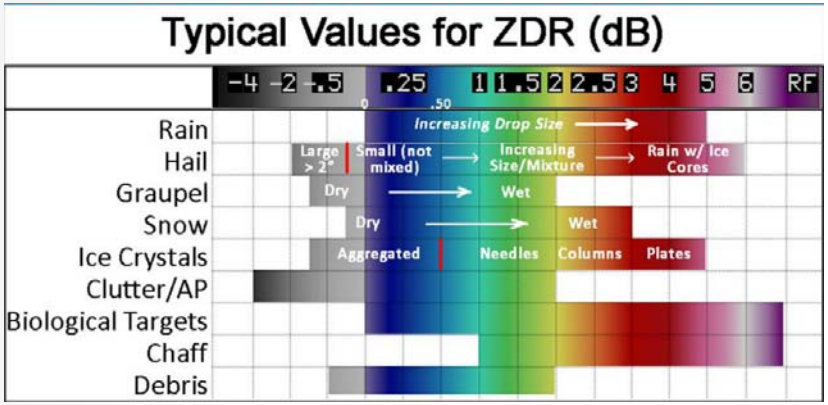
香港天文台
HONG KONG OBSERVATORY

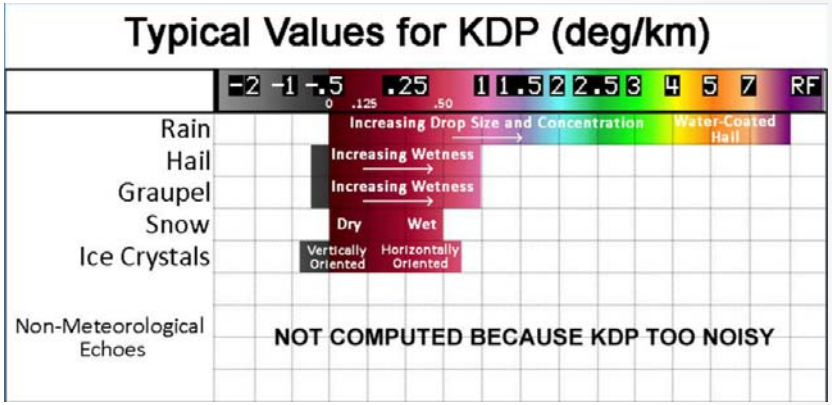
Ground Clutter

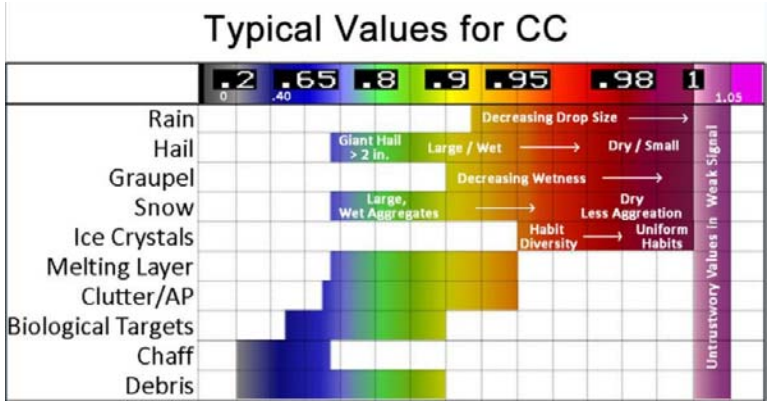




Combined Interpretation



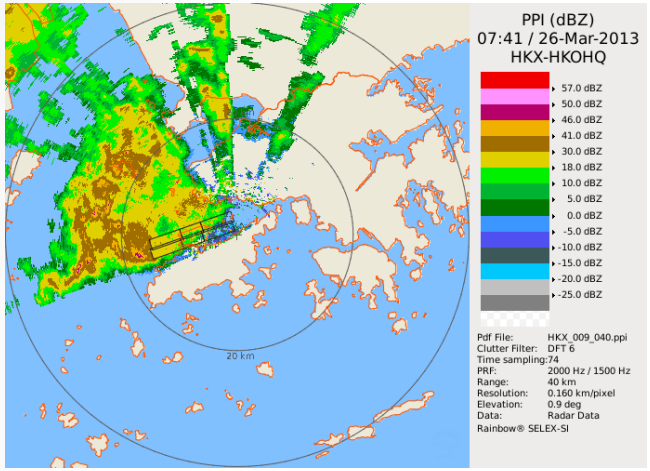


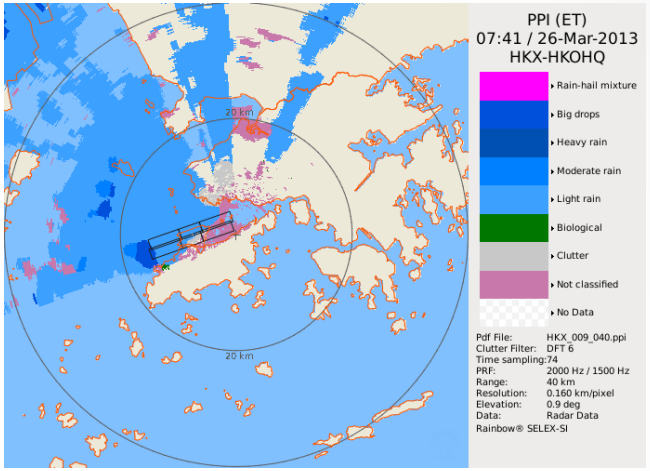


香港天文台
HONG KONG OBSERVATORY

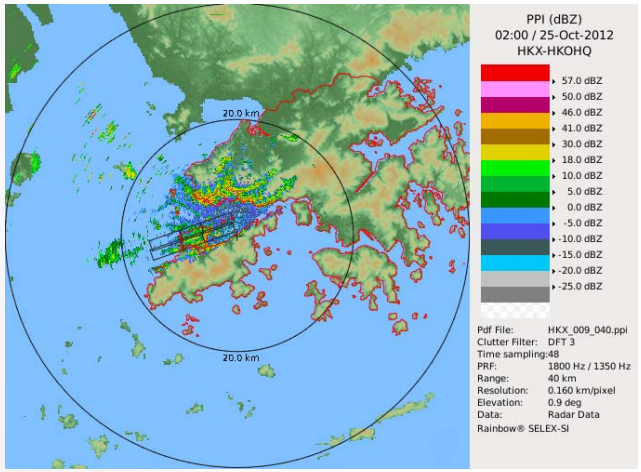
Hydrometeor Classification

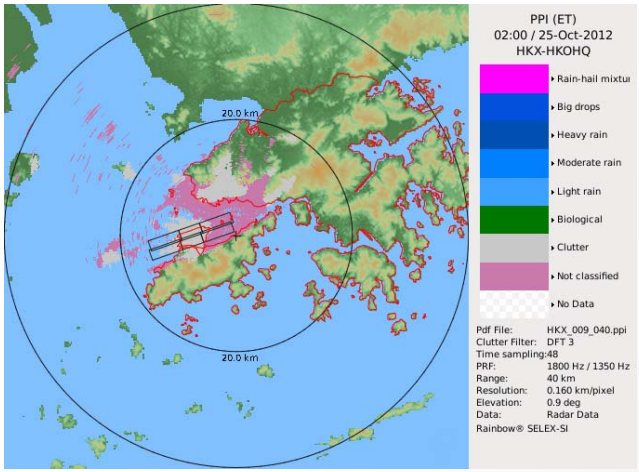
Case I: Rainstorms





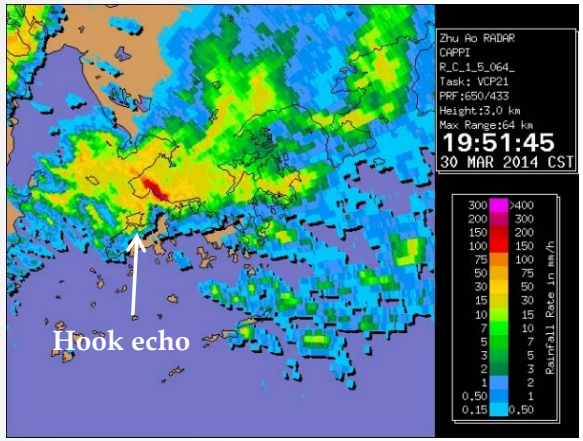
Case II: Clutters under fine weather

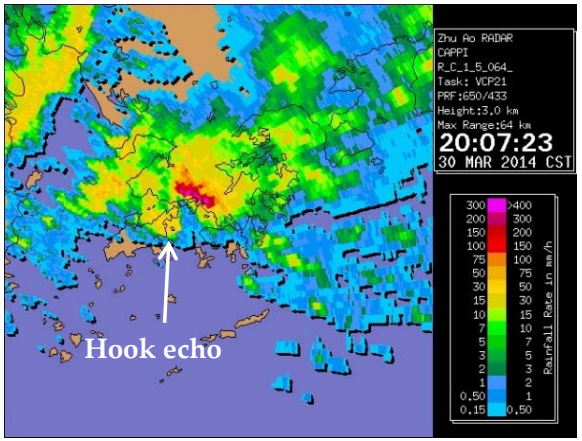


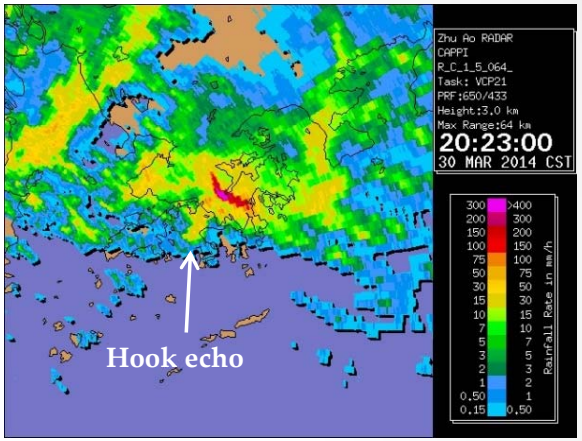


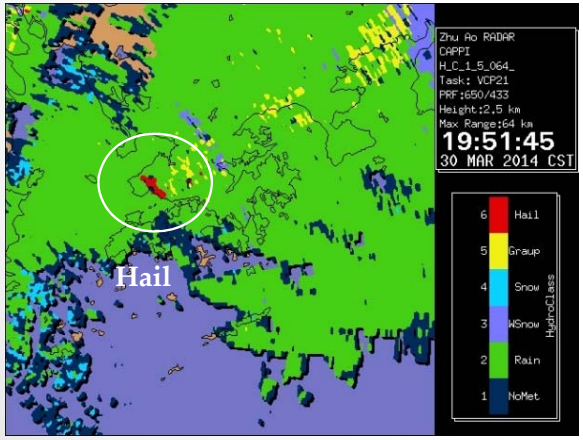
香港天文台
HONG KONG OBSERVATORY

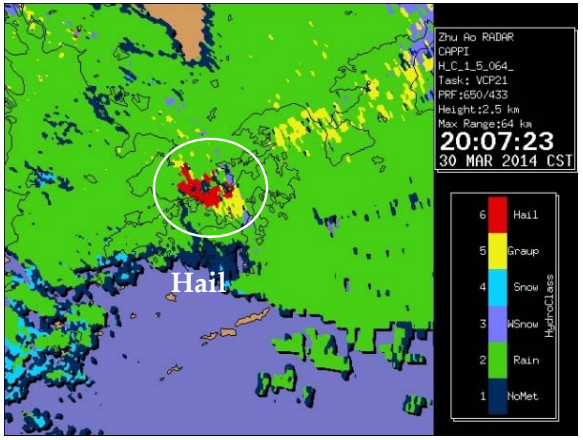
Hydrometeor Classification

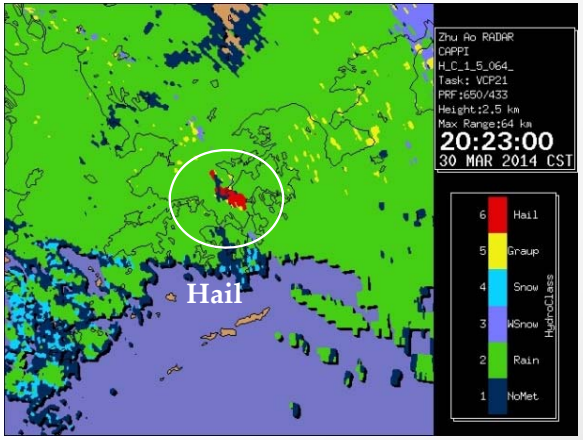












香港天文台
HONG KONG OBSERVATORY

Dual-polarization QPE

- R(Z)

  $R(Z)=A*Z^{B}$

  (A=0.0364, B=0.625)

- R(KDP)

  $R(Z)=A*KDP^{B}$

  (A = 33.33, B = 0.8695)

- R(KDP,ZDR)

  $R(Z,KDPR)=A*KDP^{B}/(a+b*(ZDR-1)^{c})$

  (A = 44.0, B = 0.822, a = 0.4, b = 3.5, c = 1.7)

香港天文台
HONG KONG OBSERVATORY

Dual-polarization QPE

- R(Z,ZDR)
  R(Z,ZDR)=A*Z^B/(a+b*(ZDR-1)^c)
  (A = 0.036463, B = 0.625, a = 0.4, b = 5.0, c = 1.3)

- NSSL2005
  - R(Z,ZDR) , when R(Z)<R0
  - R(KDP,ZDR),when R(z) =>R0
  - R(KDP) ,when R(z) =>R1

  Default R0=6,R1=50 (configurable in IRIS)

Content

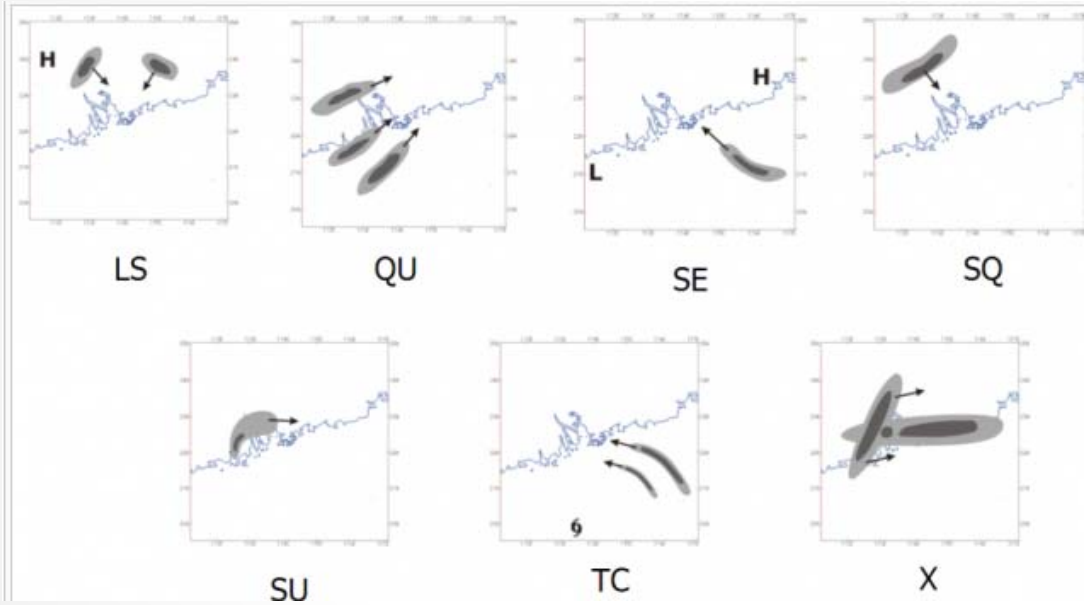
- Radar QPE
- Dual-polarization Weather Radar
- Interpretation of Extreme Weather on Radar Imagery
- Other Possible Scanning Strategy – 1-min Rapid Scan

香港天文台
HONG KONG OBSERVATORY

Rainstorm Characteristics

Rainstorm characteristics

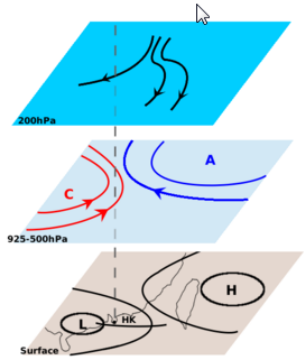
- from radar perspective
- from synoptic forcing perspective



Forcing Type: MTS

Monsoon Trough South (MTS)

MTS occurs over the south China coast or northern part of the South China Sea (SCS) when the SW monsoonal flow converges with SE'lies at the SW flank of the Pacific ridge. Depending on the relative dominance of the Pacific ridge and SW monsoonal flows, MTS usually appears as a broad trough over the SCS. Intense and persistent convections will form over the trough, usually in form of NW-SE oriented lines of intense rain echoes with continuous development, and move towards south China coastal areas.

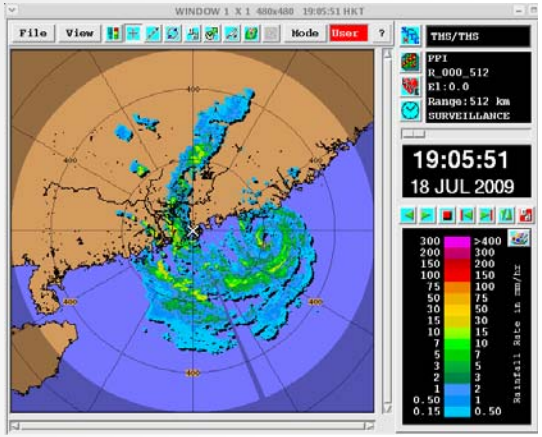


Type Summary

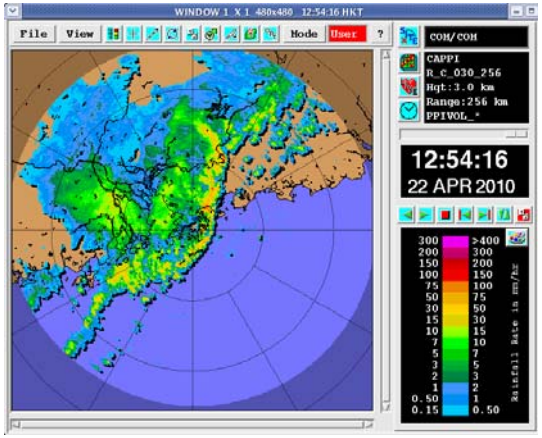
238	2010-07-28 14:30	Black
248	2011-05-22 10:45	Red
206	2008-07-12 02:15	Red
122	2003-05-05 01:45	Amber
236	2010-06-28 12:45	Amber
235	2010-06-27 12:50	Amber
234	2010-06-26 03:58	Amber
207	2008-07-14 23:25	Amber
192	2007-06-29 05:40	Amber
178	2006-07-28 03:25	Amber
121	2003-05-04 18:55	Amber
123	2003-05-05 22:20	Amber
90	2001-07-21 03:15	Amber
87	2001-07-15 14:45	Amber
83	2001-06-26 15:00	Amber
82	2001-06-25 18:05	Amber
60	2000-08-04 14:40	Amber
59	2000-08-04 07:35	Amber
58	2000-08-03 11:15	Amber
57	2000-08-03 05:40	Amber

Common Radar Products Used by HKO

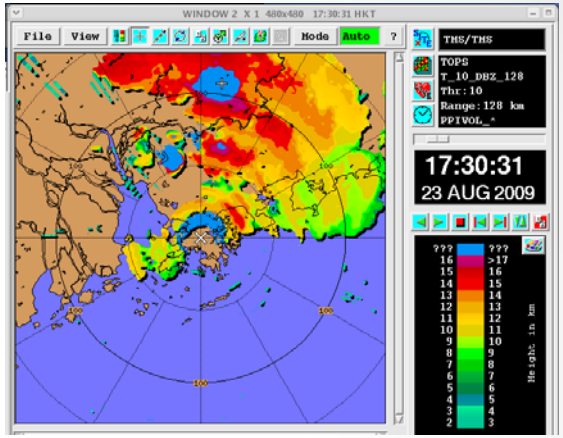
香港天文台
HONG KONG OBSERVATORY



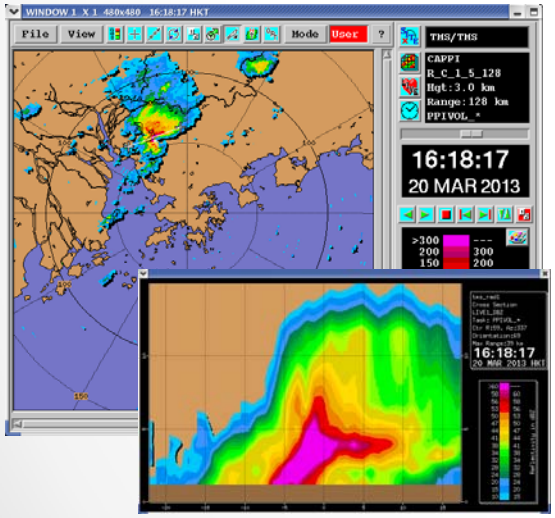
PPI (Plan Position Indicator)



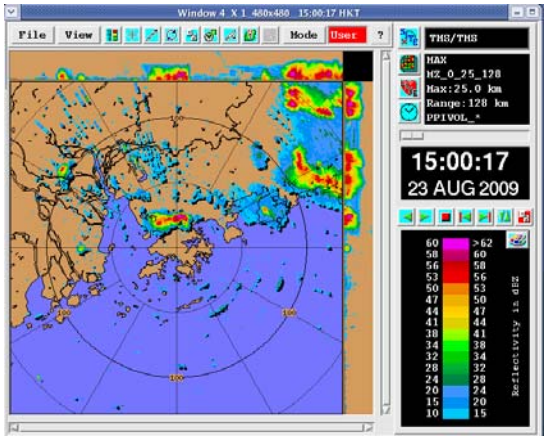
CAPPI (Constant Altitude PPI)



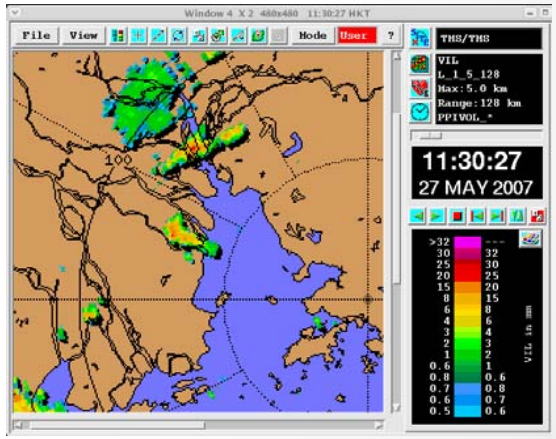
TOPS
height of echo top of 10 dBZ surface



Cross-section



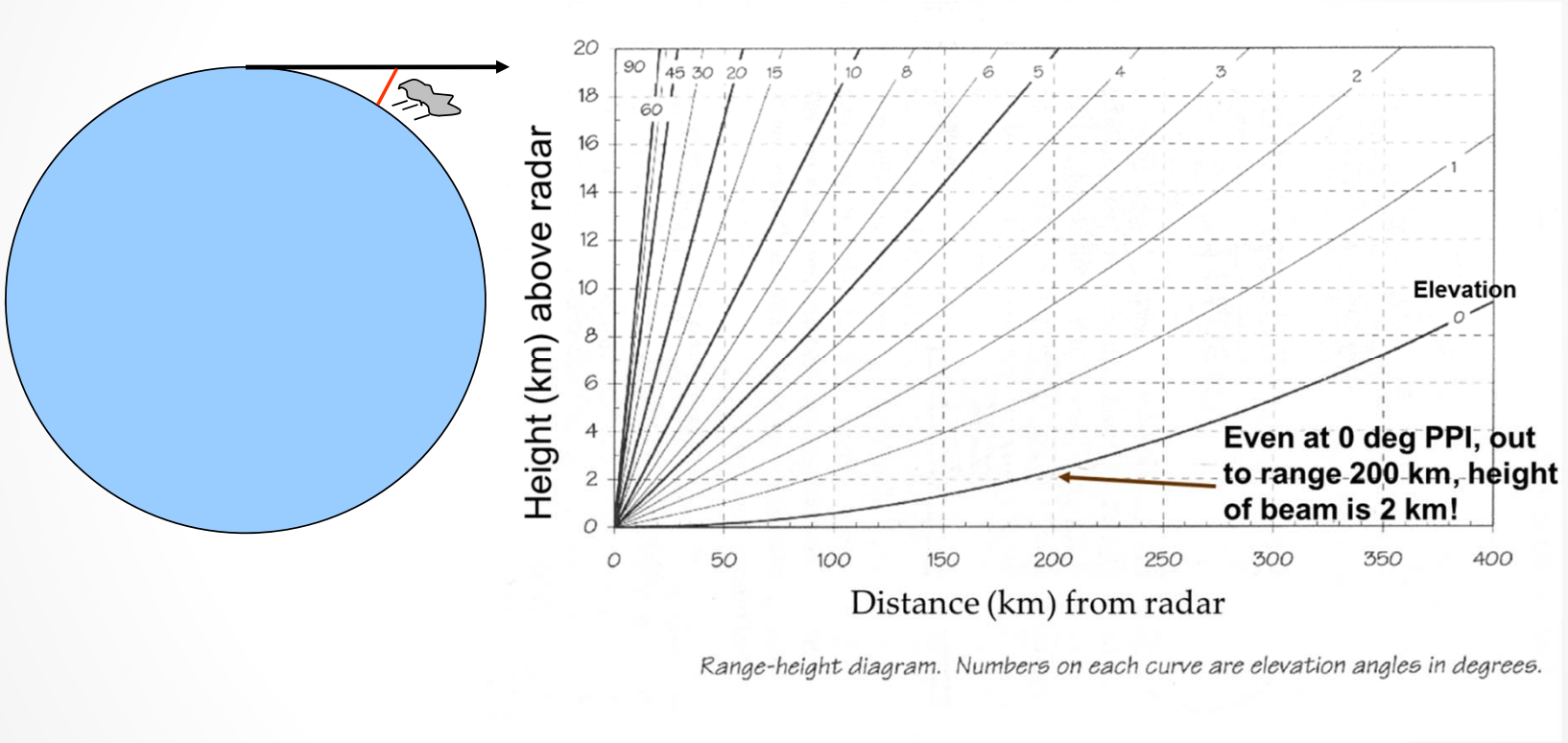
MAX
(the maximum reflectivity above each pixel)



VIL (Vertical Integrated Liquid)
High VIL (e.g. > 20 mm) is a good indicator of severe storm and hail.

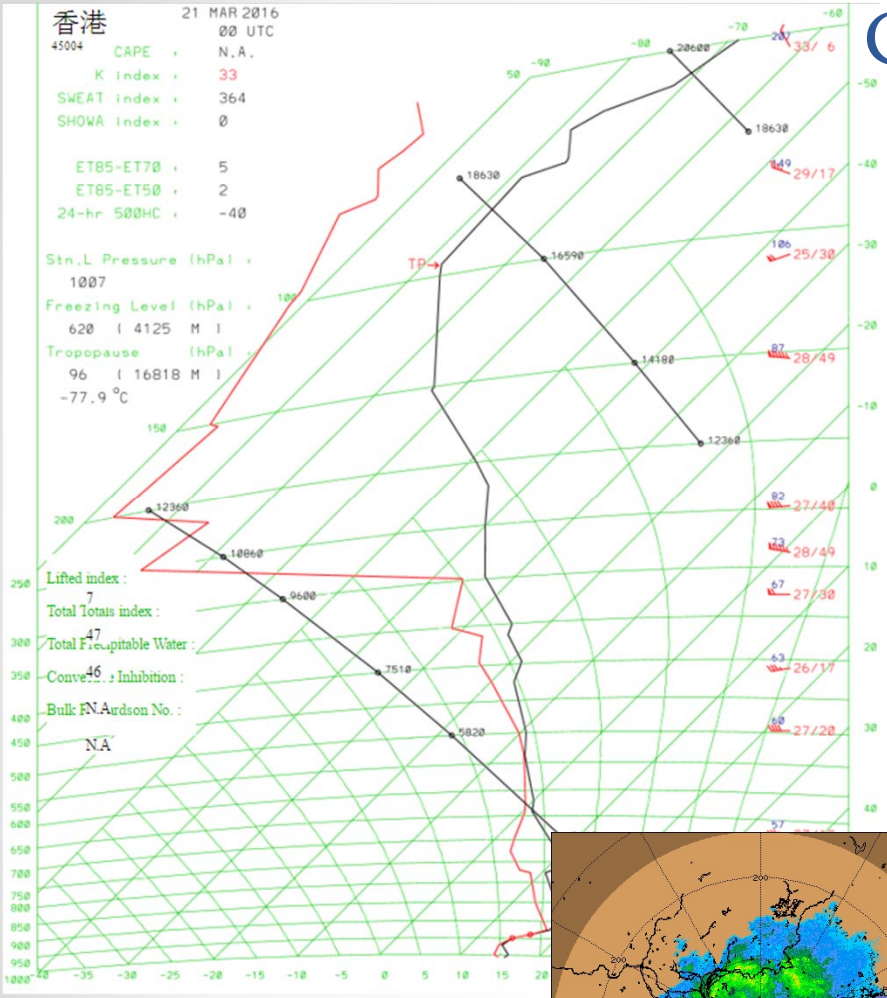
香港天文台
HONG KONG OBSERVATORY

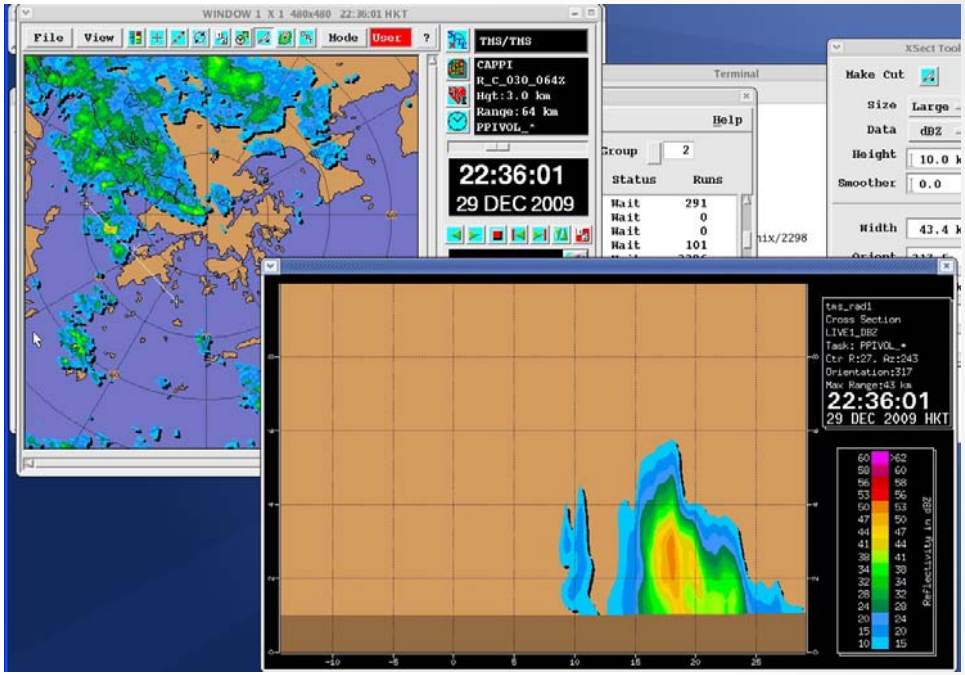
Earth's curvature



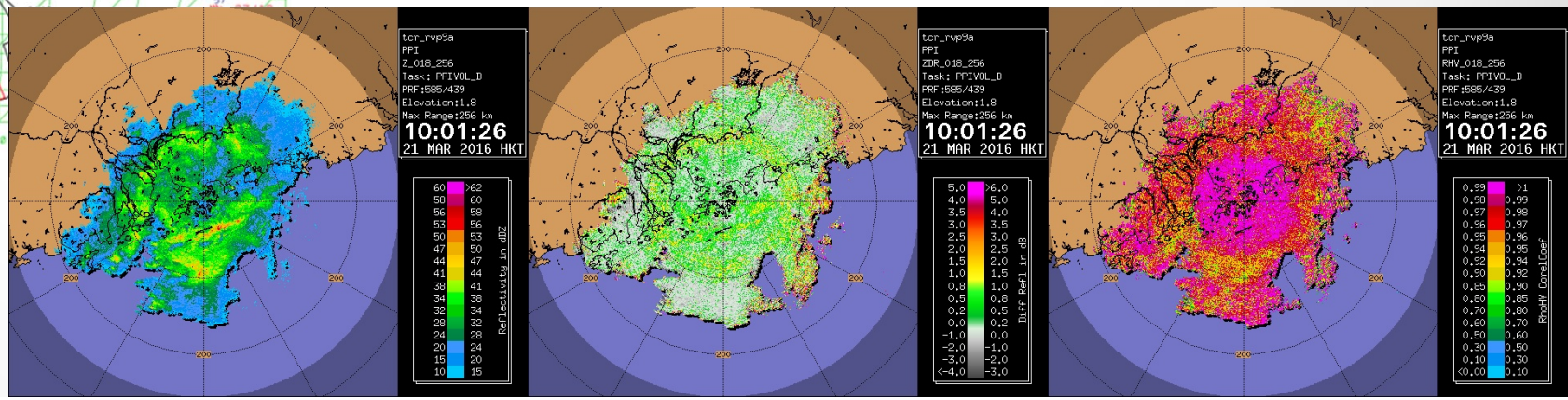
Range-height diagram. Numbers on each curve are elevation angles in degrees.

Cross-section





- Core reflectivity below freezing level?

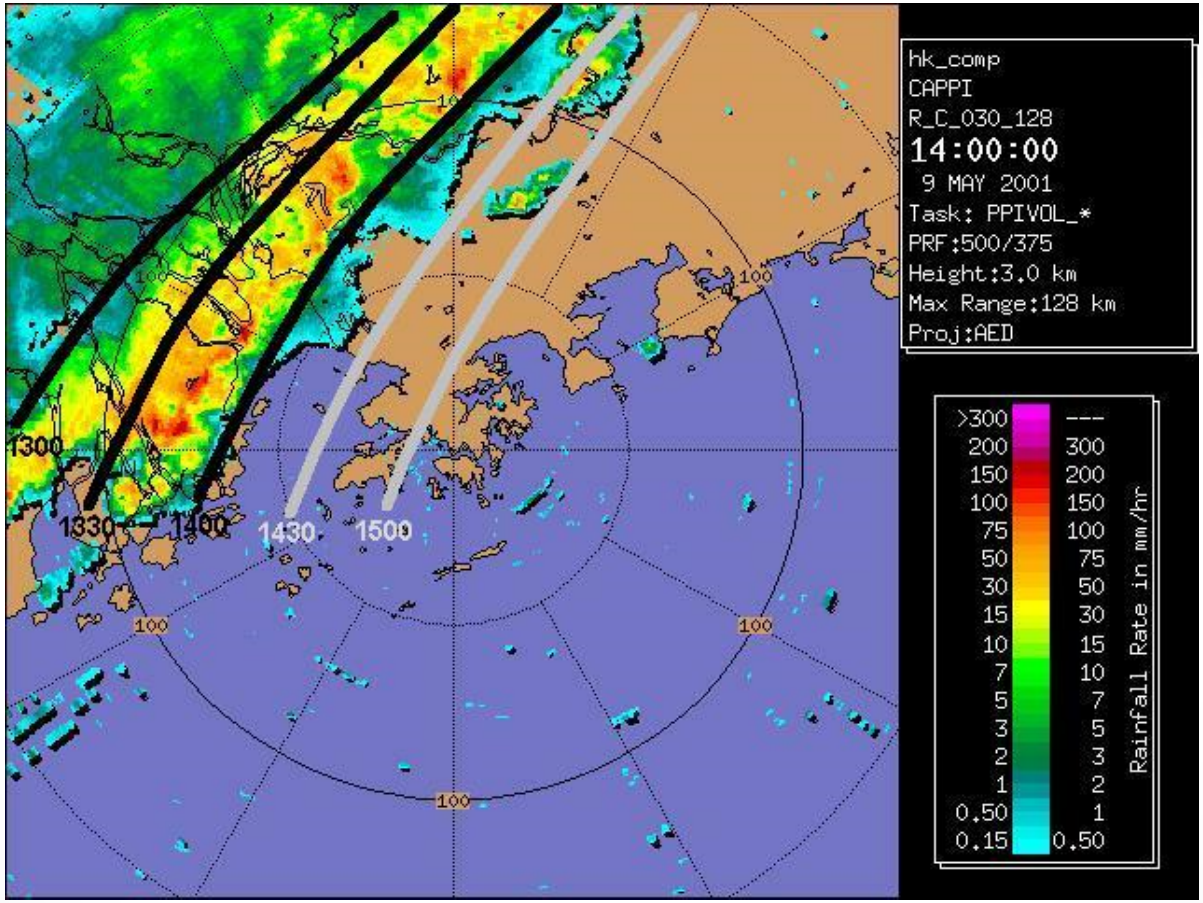


香港天文台
HONG KONG OBSERVATORY

Interpretation of Extreme Weather on Radar Imagery

香港天文台
HONG KONG OBSERVATORY

Extrapolation to deduce arrival time of rainband

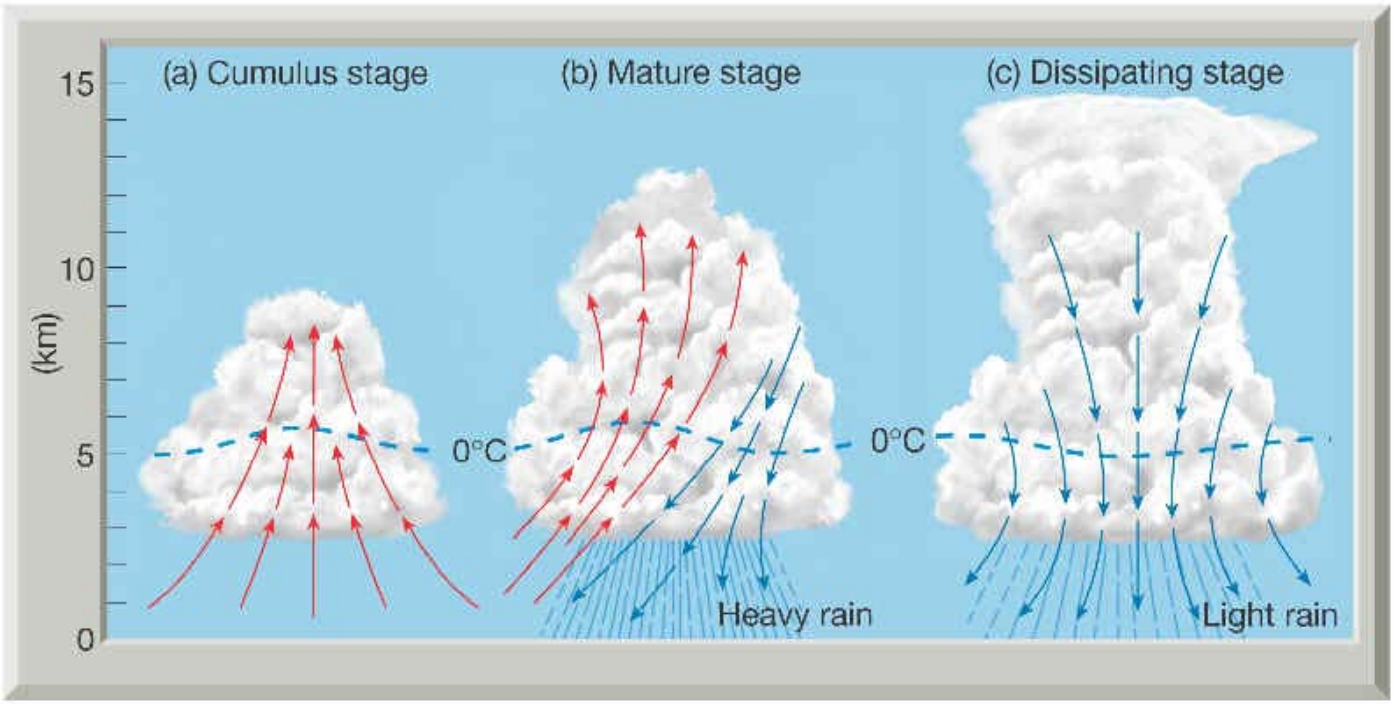


香港天文台
HONG KONG OBSERVATORY

Doppler velocity image

香港天文台
HONG KONG OBSERVATORY

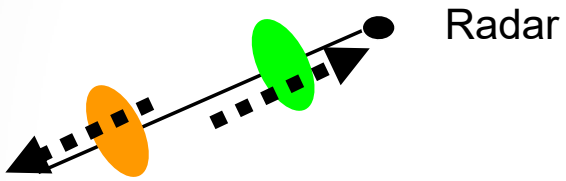
Storm Development on Radarscope



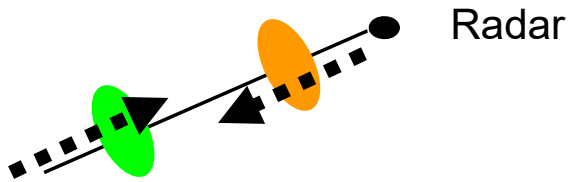
Typical Life Cycle of Storms

Identifying Convergence/Divergence on Doppler velocity PPI images

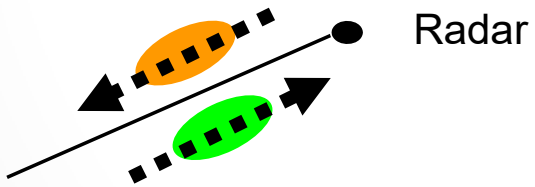
- Look for ‘dipoles’ of warm/cold colors along a radial to identify convergence/divergence, or on either side of a radial to identify cyclonic/anti-cyclonic signatures



Divergence

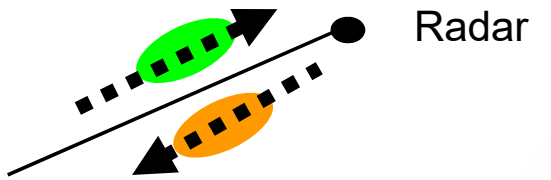


Convergence



Cyclonic signature

(anti-clockwise)

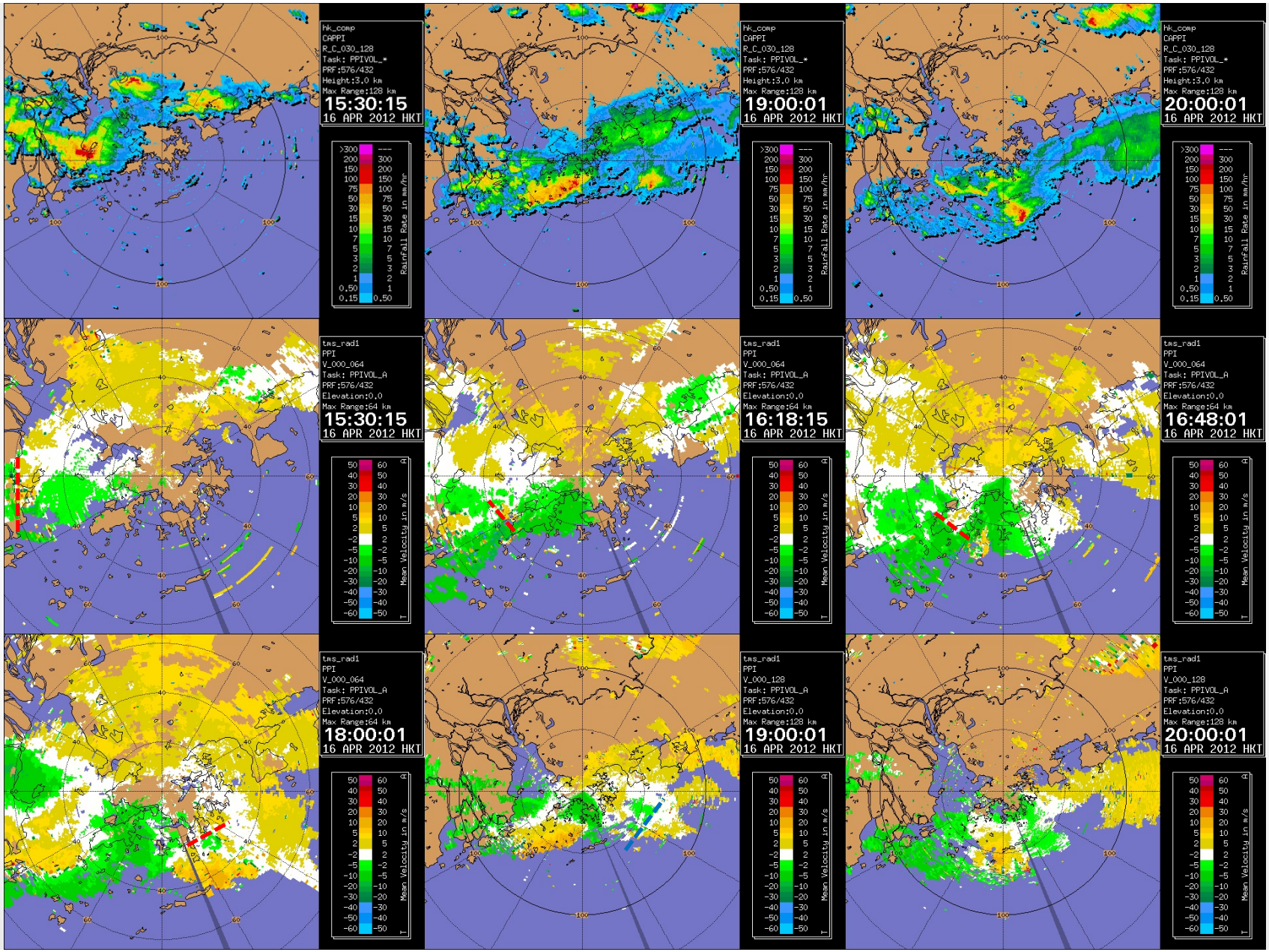


Anti-cylonic signature

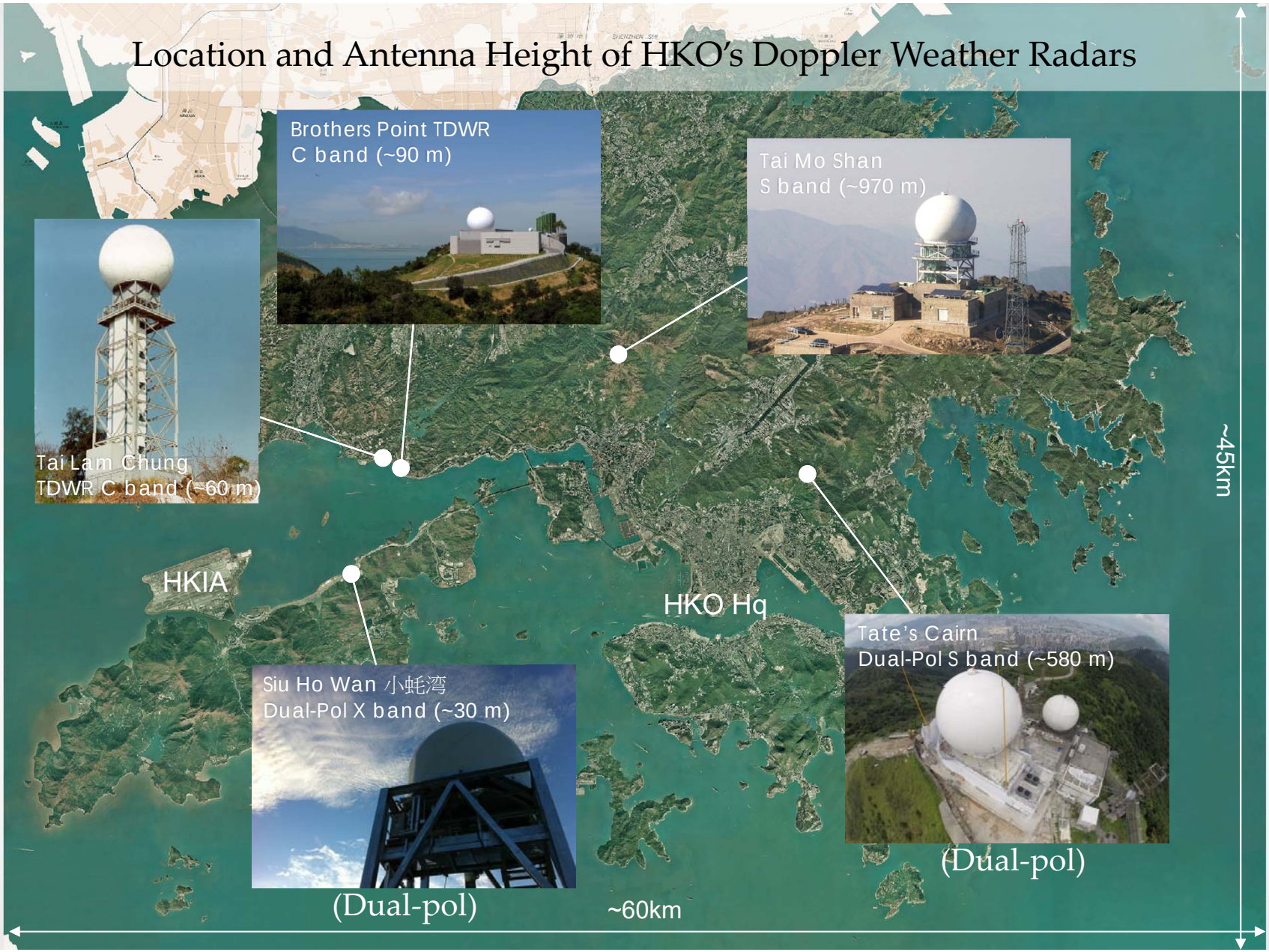
(clockwise)

香港天文台
HONG KONG OBSERVATORY

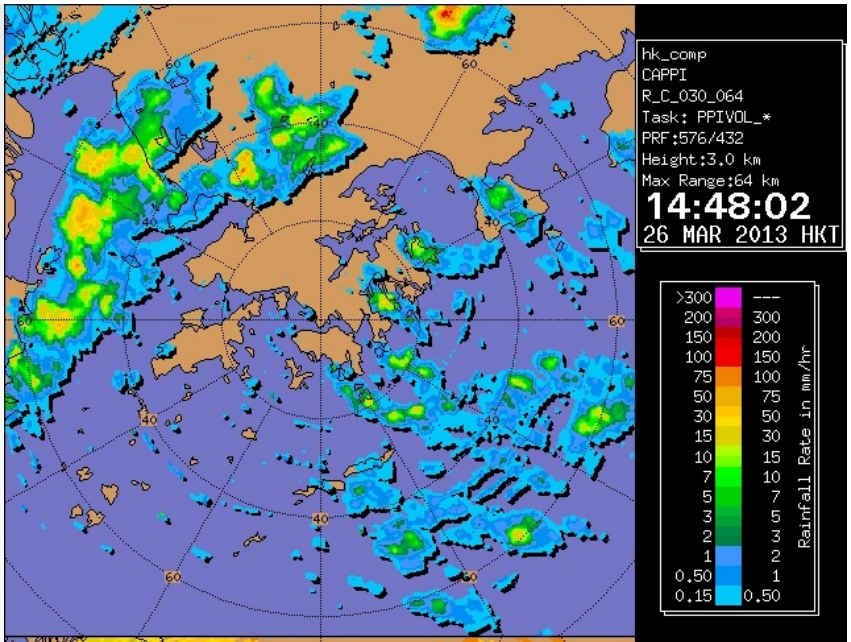
Case Study I

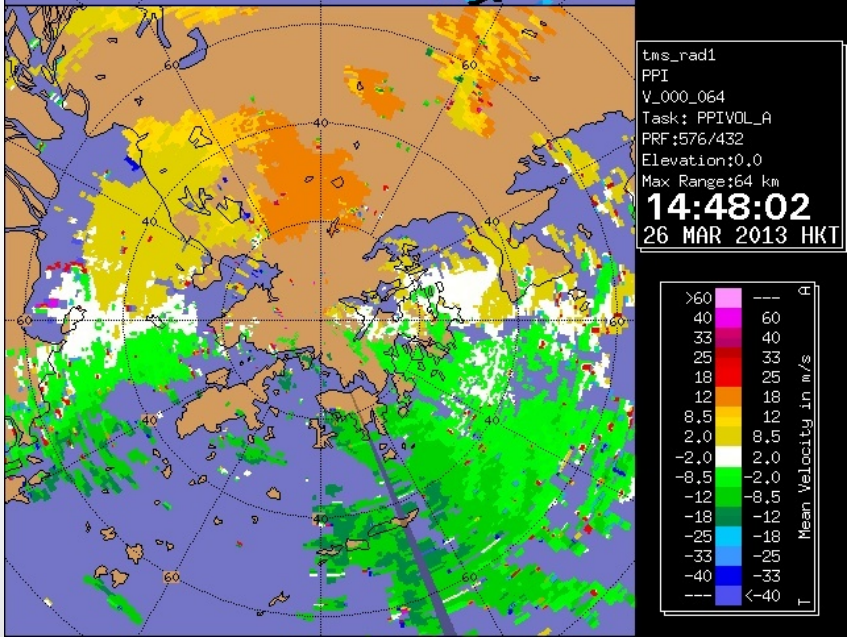

hk_comp
CAPPI
R_C_030_128
Task: PPIVOL_*
PRF:576/432
Height:3.0 km
Max Range:128 km
15:30:15
16 APR 2012 HKT
Rainfall Rate in mm/hr
hk_comp
CAPPI
R_C_030_128
Task: PPIVOL_*
PRF:576/432
Height:3.0 km
Max Range:128 km
19:00:01
16 APR 2012 HKT
Rainfall Rate in mm/hr
hk_comp
CAPPI
R_C_030_128
Task: PPIVOL_*
PRF:576/432
Height:3.0 km
Max Range:128 km
20:00:01
16 APR 2012 HKT
Rainfall Rate in mm/hr
tms_rad1
PPI
V_000_064
Task: PPIVOL_A
PRF:576/432
Elevation:0.0
Max Range:64 km
15:30:15
16 APR 2012 HKT
Mean Velocity in m/s
tms_rad1
PPI
V_000_064
Task: PPIVOL_A
PRF:576/432
Elevation:0.0
Max Range:64 km
16:18:15
16 APR 2012 HKT
Mean Velocity in m/s
tms_rad1
PPI
V_000_064
Task: PPIVOL_A
PRF:576/432
Elevation:0.0
Max Range:64 km
16:48:01
16 APR 2012 HKT
Mean Velocity in m/s
tms_rad1
PPI
V_000_064
Task: PPIVOL_A
PRF:576/432
Elevation:0.0
Max Range:64 km
18:00:01
16 APR 2012 HKT
Mean Velocity in m/s
tms_rad1
PPI
V_000_128
Task: PPIVOL_A
PRF:576/432
Elevation:0.0
Max Range:128 km
19:00:01
16 APR 2012 HKT
Mean Velocity in m/s
tms_rad1
PPI
V_000_128
Task: PPIVOL_A
PRF:576/432
Elevation:0.0
Max Range:128 km
20:00:01
16 APR 2012 HKT
Mean Velocity in m/s

Location and Antenna Height of HKO's Doppler Weather Radars

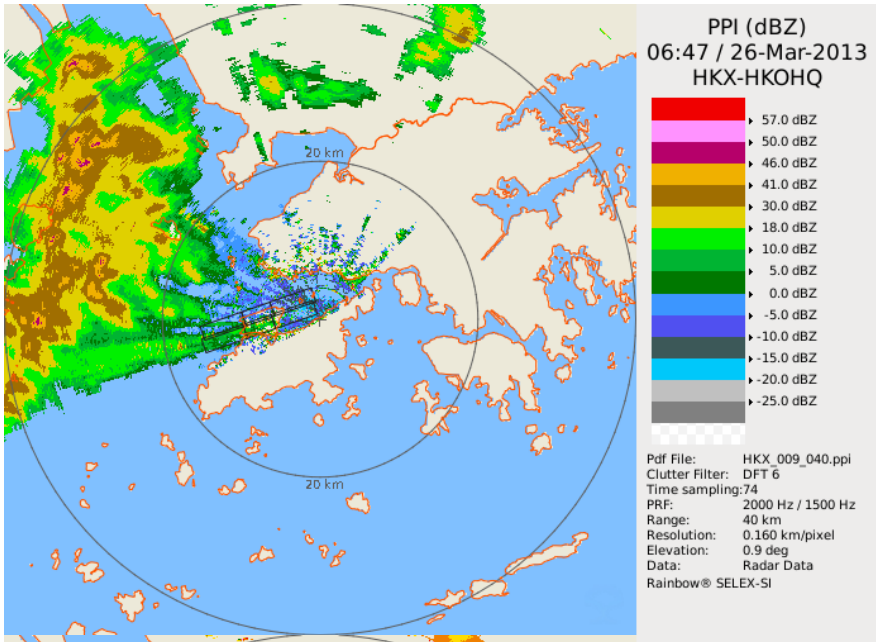


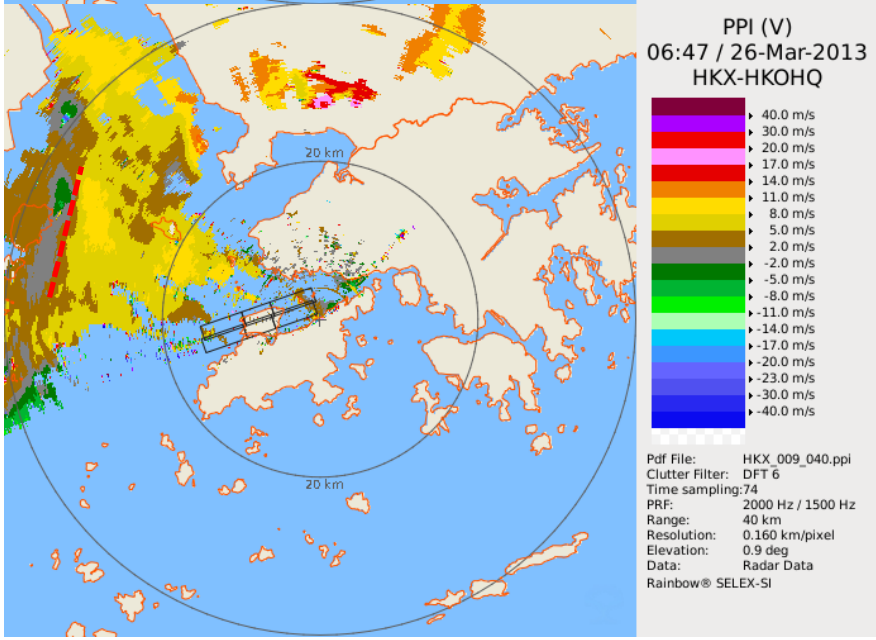
TMSWR (Antenna Height ~1km)





No convergence on Doppler imagery of TMSWR

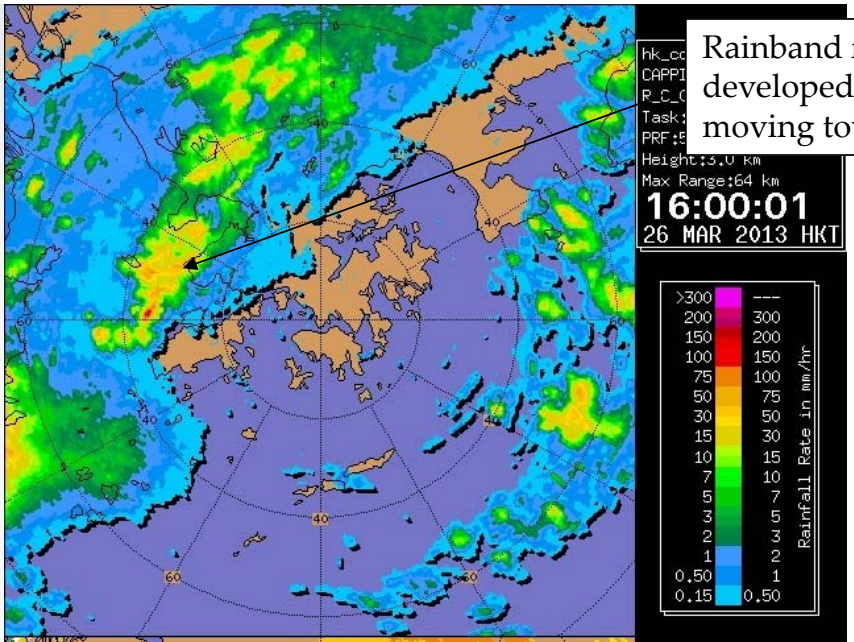


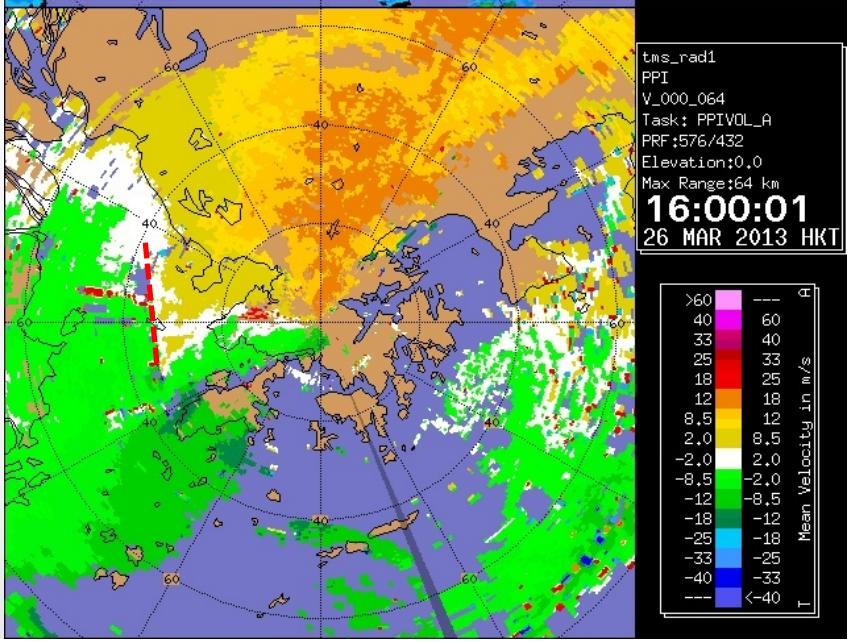


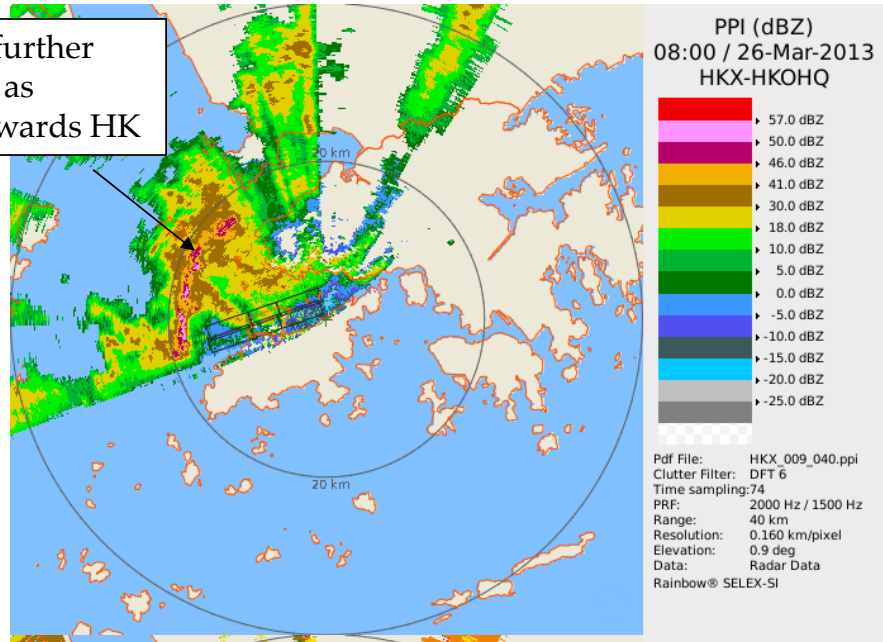
X-band Radar (Antenna Height ~32m)

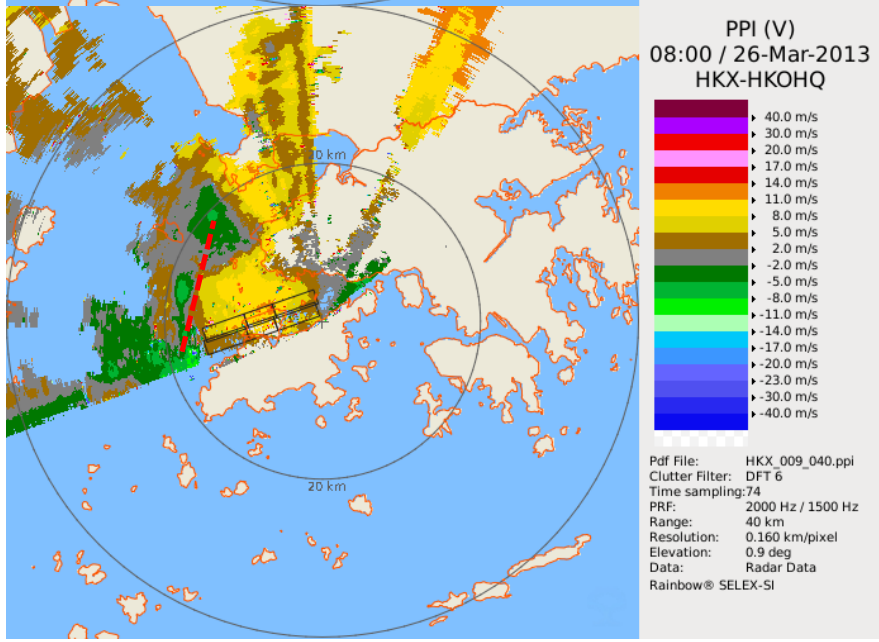
Convergence identified, the rainband is expected to maintain or further develop

TMSWR (Antenna Height ~1km)







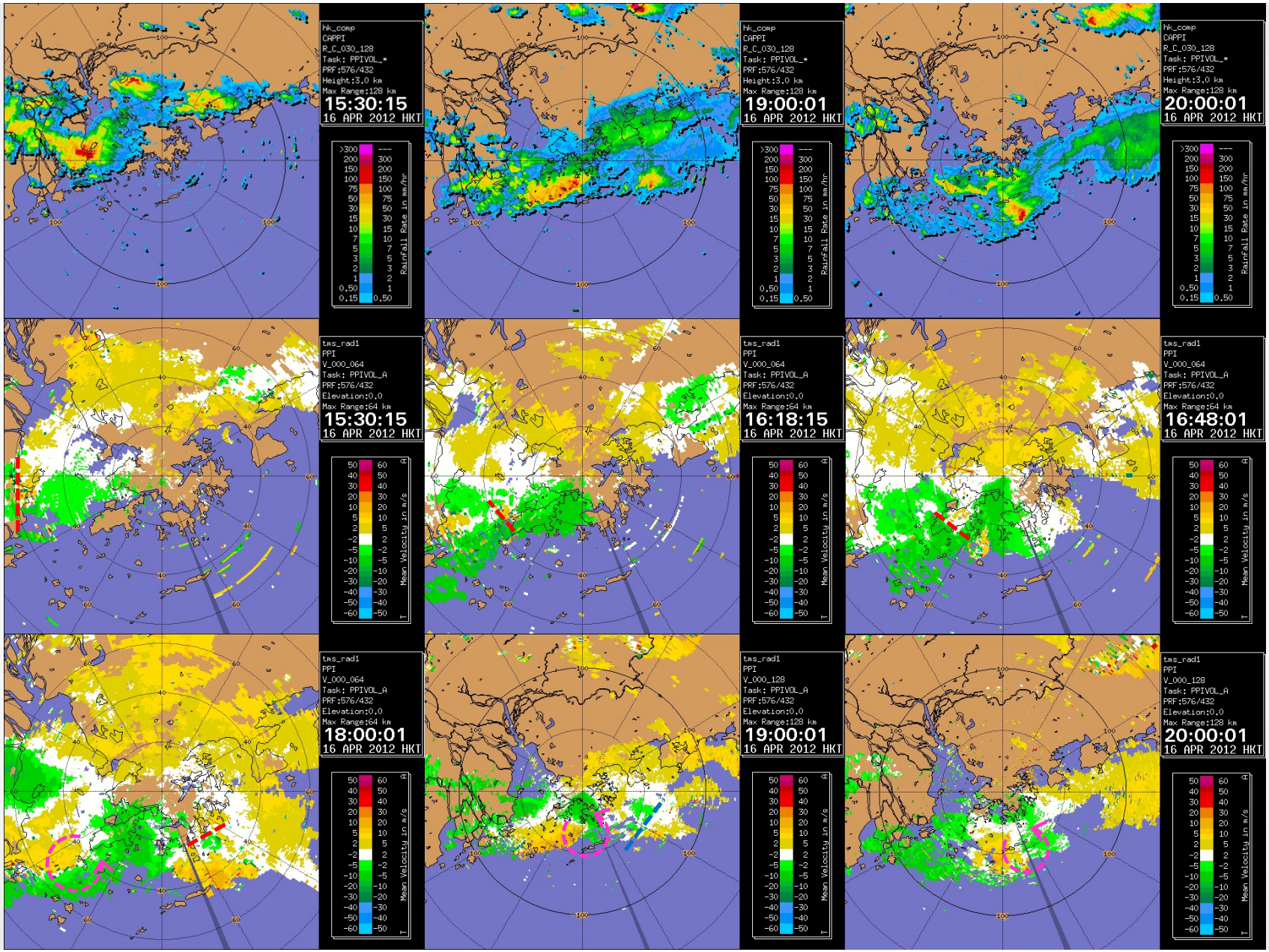


Convergence also identified on TMSWR's Doppler imagery

Convergence identified, the rainband is expected to maintain or further develop

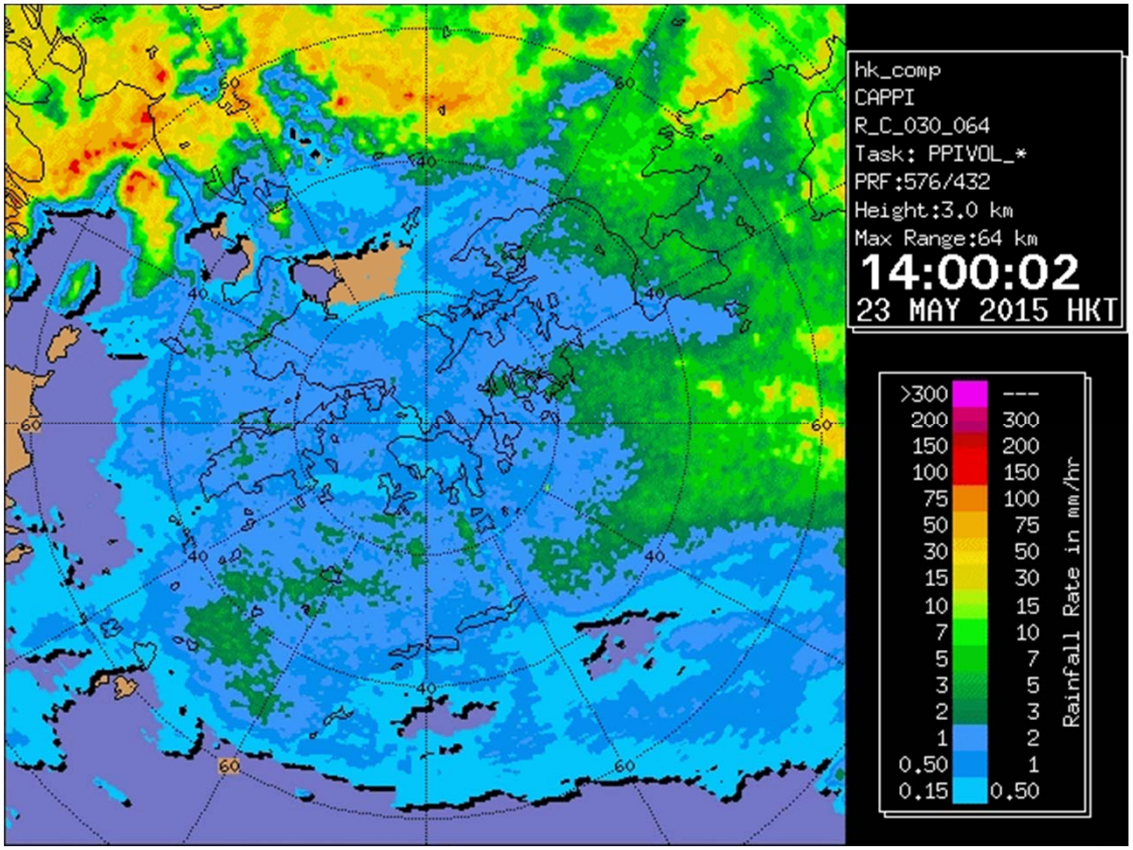
香港天文台
HONG KONG OBSERVATORY

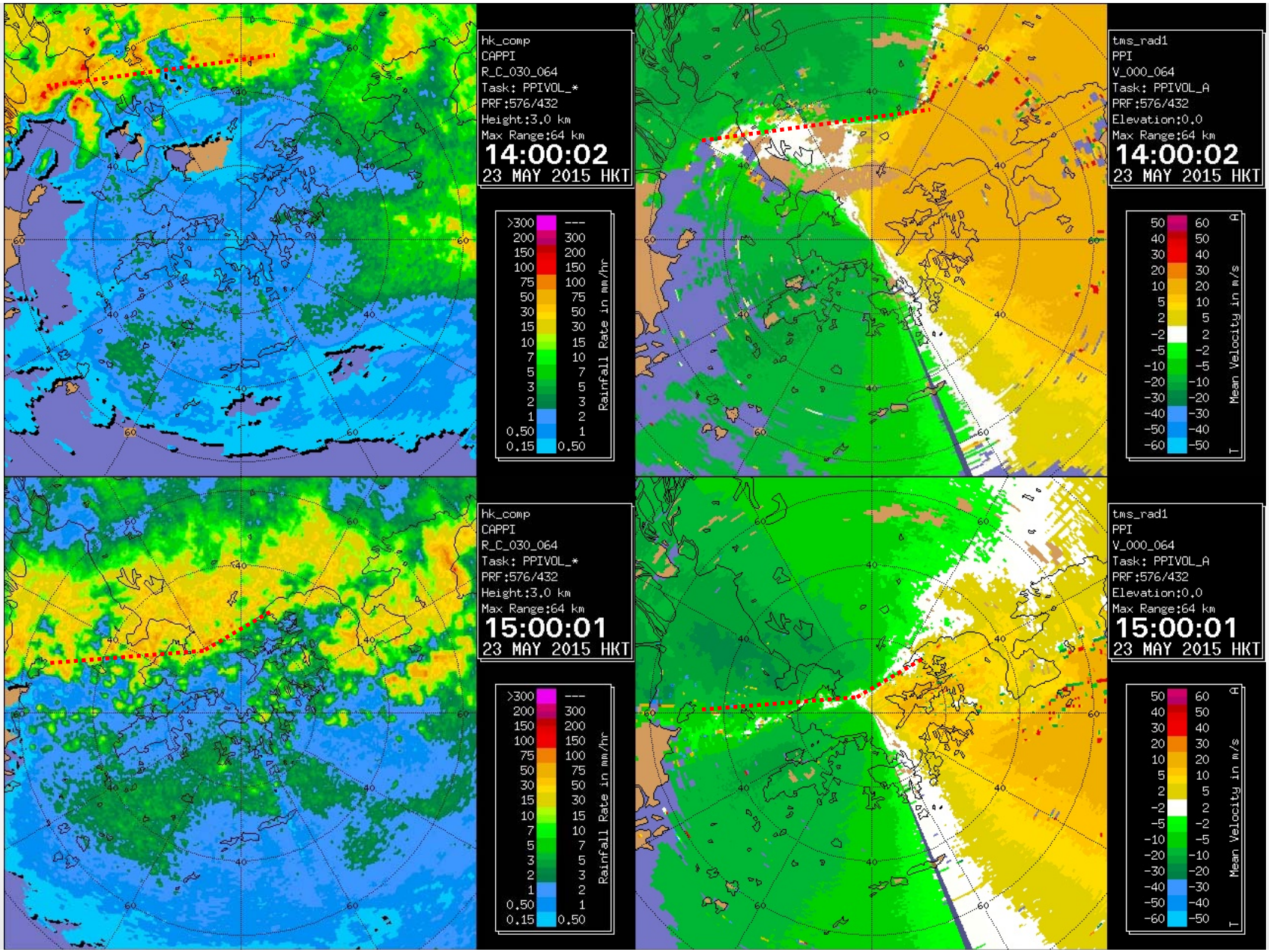
Case Study II: 16 April 2012

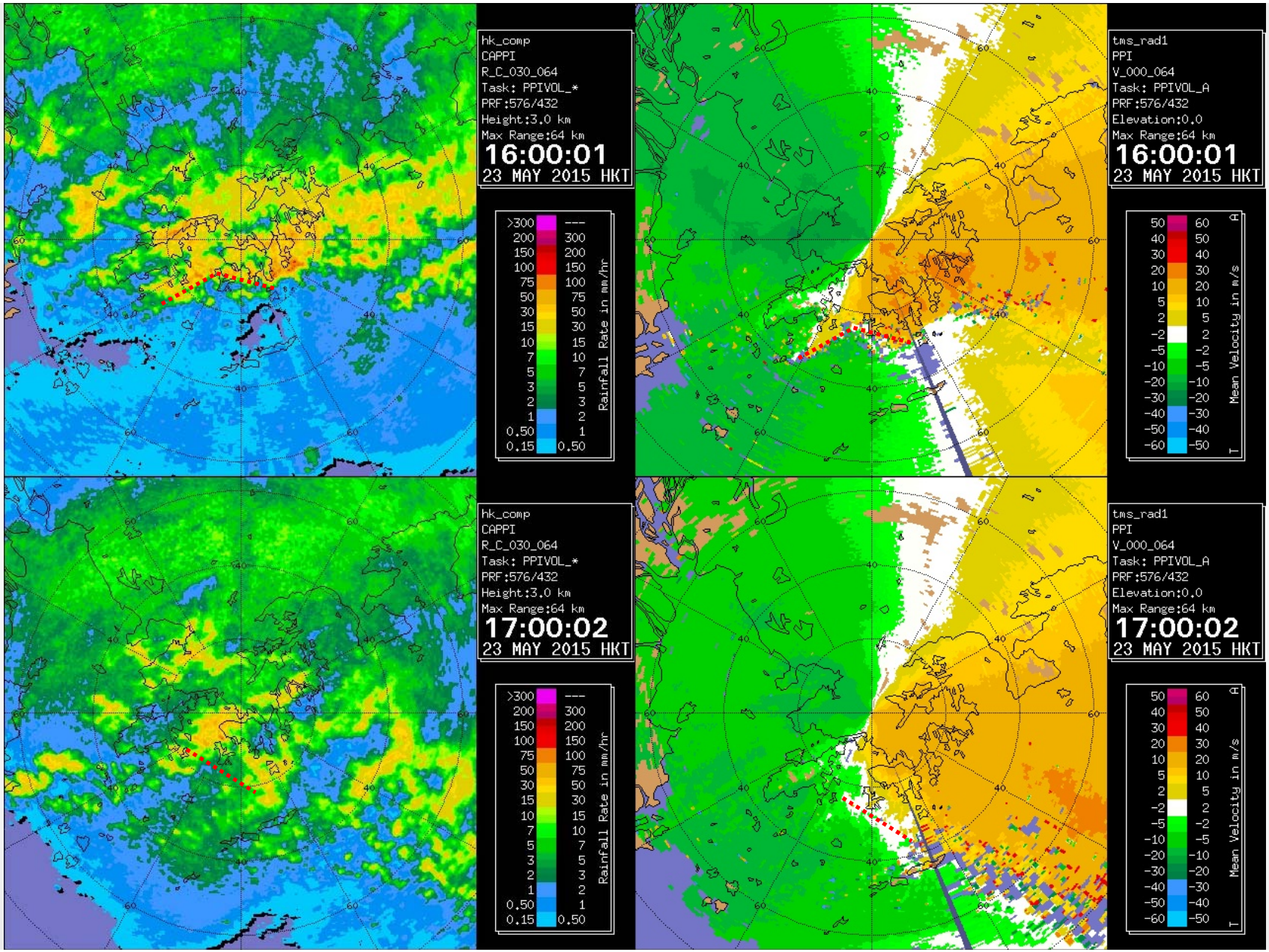

hk_comp
CAPPI
R_C_030_128
Task: PPIVOL_*
PRF:576/432
Height:3.0 km
Max Range:128 km
15:30:15
16 APR 2012 HKT
Rainfall Rate in mm/hr
hk_comp
CAPPI
R_C_030_128
Task: PPIVOL_*
PRF:576/432
Height:3.0 km
Max Range:128 km
19:00:01
16 APR 2012 HKT
Rainfall Rate in mm/hr
hk_comp
CAPPI
R_C_030_128
Task: PPIVOL_*
PRF:576/432
Height:3.0 km
Max Range:128 km
20:00:01
16 APR 2012 HKT
Rainfall Rate in mm/hr
tms_rad1
PPI
V_000_064
Task: PPIVOL_A
PRF:576/432
Elevation:0.0
Max Range:64 km
15:30:15
16 APR 2012 HKT
Mean Velocity in m/s
tms_rad1
PPI
V_000_064
Task: PPIVOL_A
PRF:576/432
Elevation:0.0
Max Range:64 km
16:18:15
16 APR 2012 HKT
Mean Velocity in m/s
tms_rad1
PPI
V_000_064
Task: PPIVOL_A
PRF:576/432
Elevation:0.0
Max Range:64 km
16:48:01
16 APR 2012 HKT
Mean Velocity in m/s
tms_rad1
PPI
V_000_064
Task: PPIVOL_A
PRF:576/432
Elevation:0.0
Max Range:64 km
18:00:01
16 APR 2012 HKT
Mean Velocity in m/s
tms_rad1
PPI
V_000_128
Task: PPIVOL_A
PRF:576/432
Elevation:0.0
Max Range:128 km
19:00:01
16 APR 2012 HKT
Mean Velocity in m/s
tms_rad1
PPI
V_000_128
Task: PPIVOL_A
PRF:576/432
Elevation:0.0
Max Range:128 km
20:00:01
16 APR 2012 HKT
Mean Velocity in m/s

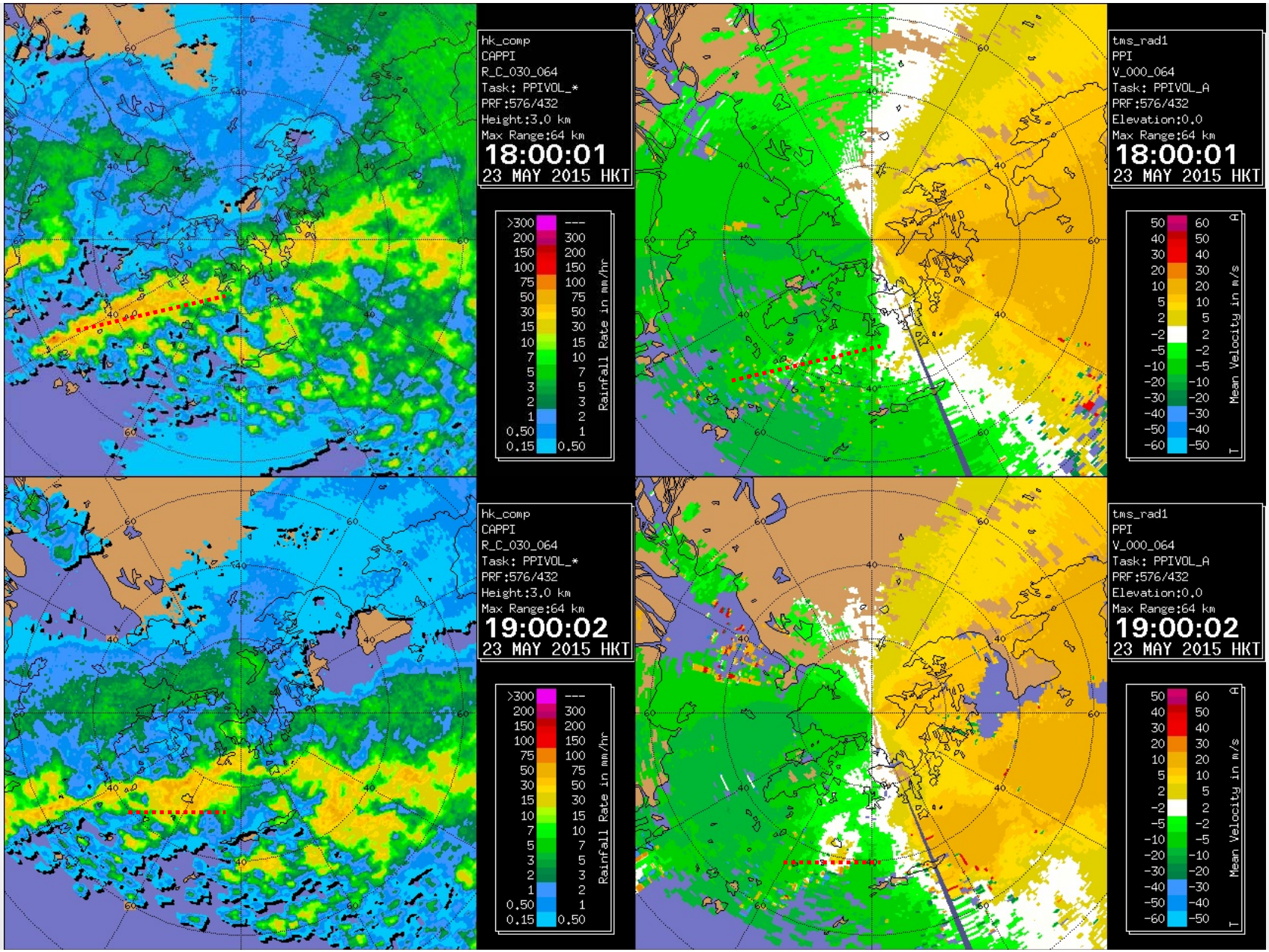
香港天文台
HONG KONG OBSERVATORY

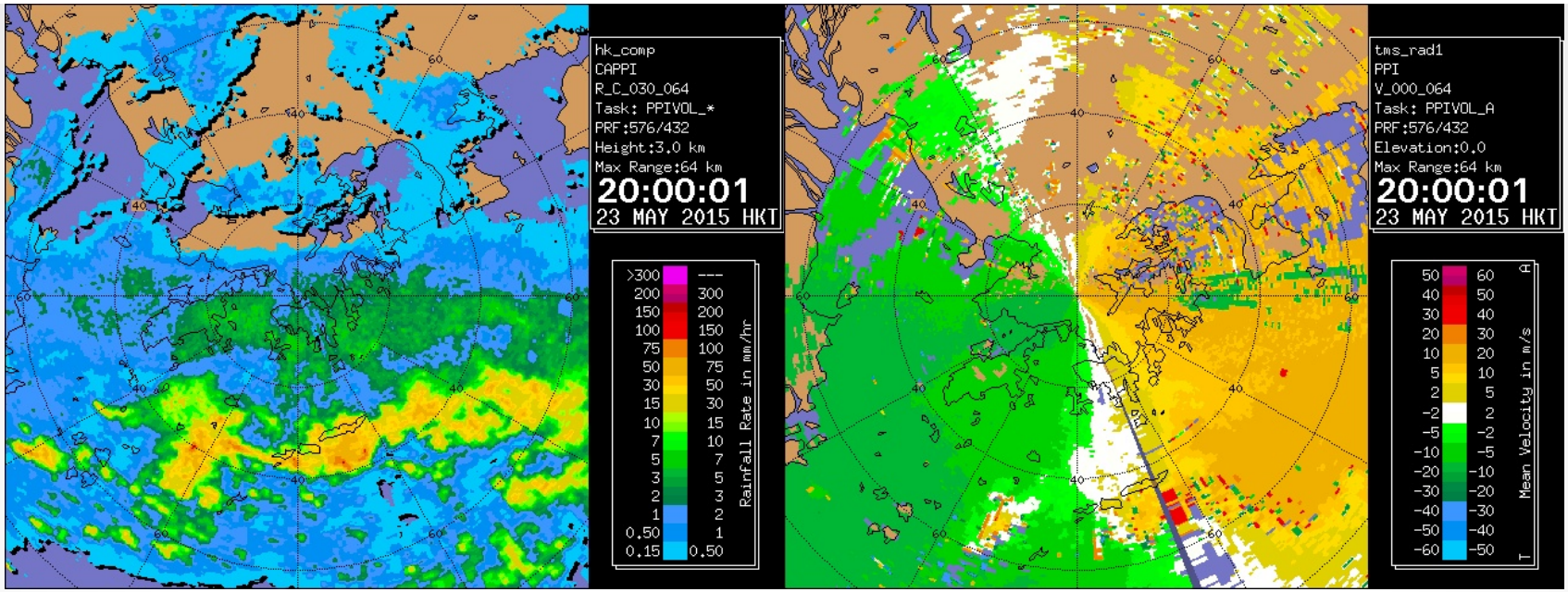
Case Study III: 23 May 2015




hk_comp
CAPPI
R_C_030_064
Task: PPIVOL_*
PRF:576/432
Height:3.0 km
Max Range:64 km
14:00:02
23 MAY 2015 HKT
>300 200 150 100 75 50 30 15 10 7 5 3 2 1 0.50 0.15
--- 300 200 150 100 75 50 30 15 10 7 5 3 2 1 0.50
Rainfall Rate in mm/hr
tms_rad1
PPI
V_000_064
Task: PPIVOL_A
PRF:576/432
Elevation:0.0
Max Range:64 km
14:00:02
23 MAY 2015 HKT
50 40 30 20 10 5 2 -2 -5 -10 -20 -30 -40 -50 -60
60 50 40 30 20 10 5 2 -2 -5 -10 -20 -30 -40 -50
A
Mean Velocity in m/s
T
hk_comp
CAPPI
R_C_030_064
Task: PPIVOL_*
PRF:576/432
Height:3.0 km
Max Range:64 km
15:00:01
23 MAY 2015 HKT
>300 200 150 100 75 50 30 15 10 7 5 3 2 1 0.50 0.15
--- 300 200 150 100 75 50 30 15 10 7 5 3 2 1 0.50
Rainfall Rate in mm/hr
tms_rad1
PPI
V_000_064
Task: PPIVOL_A
PRF:576/432
Elevation:0.0
Max Range:64 km
15:00:01
23 MAY 2015 HKT
50 40 30 20 10 5 2 -2 -5 -10 -20 -30 -40 -50 -60
60 50 40 30 20 10 5 2 -2 -5 -10 -20 -30 -40 -50
A
Mean Velocity in m/s
T

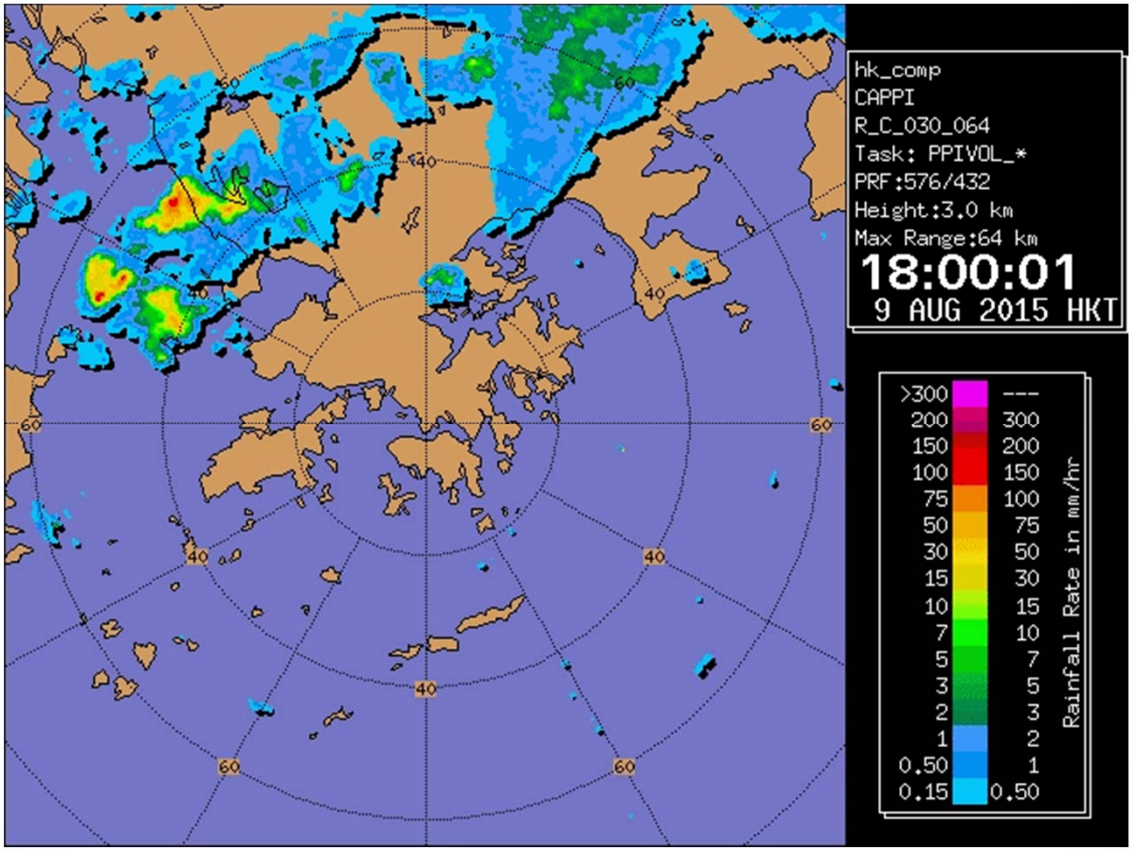

hk_comp
CAPPI
R_C_030_064
Task: PPIVOL_*
PRF:576/432
Height:3.0 km
Max Range:64 km
16:00:01
23 MAY 2015 HKT
>300 200 150 100 75 50 30 15 10 7 5 3 2 1 0.50 0.15
--- 300 200 150 100 75 50 30 15 10 7 5 3 2 1 0.50
Rainfall Rate in mm/hr
tms_rad1
PPI
V_000_064
Task: PPIVOL_A
PRF:576/432
Elevation:0.0
Max Range:64 km
16:00:01
23 MAY 2015 HKT
50 40 30 20 10 5 2 -2 -5 -10 -20 -30 -40 -50 -60
60 50 40 30 20 10 5 2 -2 -5 -10 -20 -30 -40 -50
A
Mean Velocity in m/s
T
hk_comp
CAPPI
R_C_030_064
Task: PPIVOL_*
PRF:576/432
Height:3.0 km
Max Range:64 km
17:00:02
23 MAY 2015 HKT
>300 200 150 100 75 50 30 15 10 7 5 3 2 1 0.50 0.15
--- 300 200 150 100 75 50 30 15 10 7 5 3 2 1 0.50
Rainfall Rate in mm/hr
tms_rad1
PPI
V_000_064
Task: PPIVOL_A
PRF:576/432
Elevation:0.0
Max Range:64 km
17:00:02
23 MAY 2015 HKT
50 40 30 20 10 5 2 -2 -5 -10 -20 -30 -40 -50 -60
60 50 40 30 20 10 5 2 -2 -5 -10 -20 -30 -40 -50
A
Mean Velocity in m/s
T

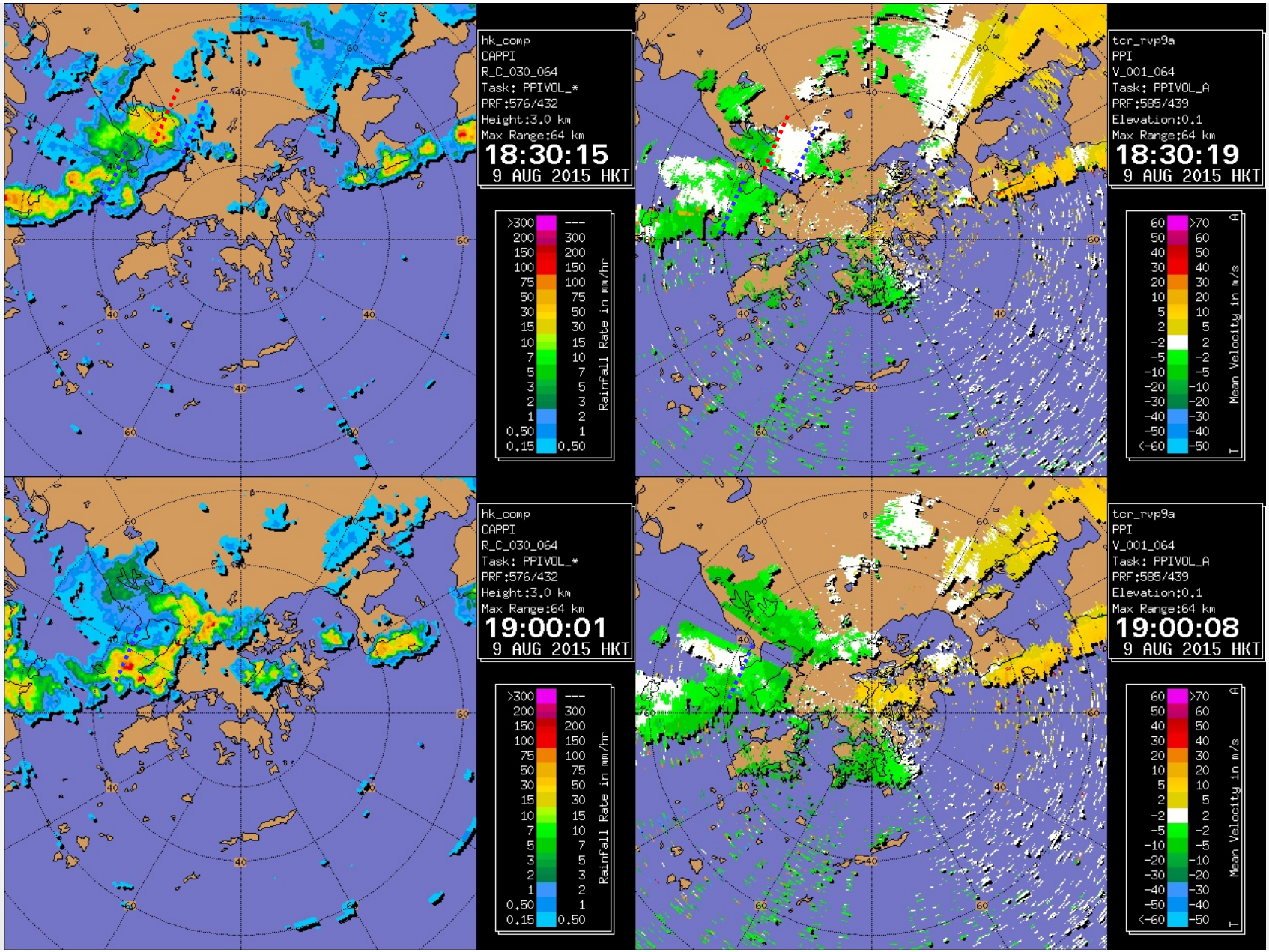

hk_comp
CAPPI
R_C_030_064
Task: PPIVOL_*
PRF:576/432
Height:3.0 km
Max Range:64 km
18:00:01
23 MAY 2015 HKT
>300 200 150 100 75 50 30 15 10 7 5 3 2 1 0.50 0.15
--- 300 200 150 100 75 50 30 15 10 7 5 3 2 1 0.50
Rainfall Rate in mm/hr
tms_rad1
PPI
V_000_064
Task: PPIVOL_A
PRF:576/432
Elevation:0.0
Max Range:64 km
18:00:01
23 MAY 2015 HKT
50 40 30 20 10 5 2 -2 -5 -10 -20 -30 -40 -50 -60
60 50 40 30 20 10 5 2 -2 -5 -10 -20 -30 -40 -50
A
Mean Velocity in m/s
T
hk_comp
CAPPI
R_C_030_064
Task: PPIVOL_*
PRF:576/432
Height:3.0 km
Max Range:64 km
19:00:02
23 MAY 2015 HKT
>300 200 150 100 75 50 30 15 10 7 5 3 2 1 0.50 0.15
--- 300 200 150 100 75 50 30 15 10 7 5 3 2 1 0.50
Rainfall Rate in mm/hr
tms_rad1
PPI
V_000_064
Task: PPIVOL_A
PRF:576/432
Elevation:0.0
Max Range:64 km
19:00:02
23 MAY 2015 HKT
50 40 30 20 10 5 2 -2 -5 -10 -20 -30 -40 -50 -60
60 50 40 30 20 10 5 2 -2 -5 -10 -20 -30 -40 -50
A
Mean Velocity in m/s
T

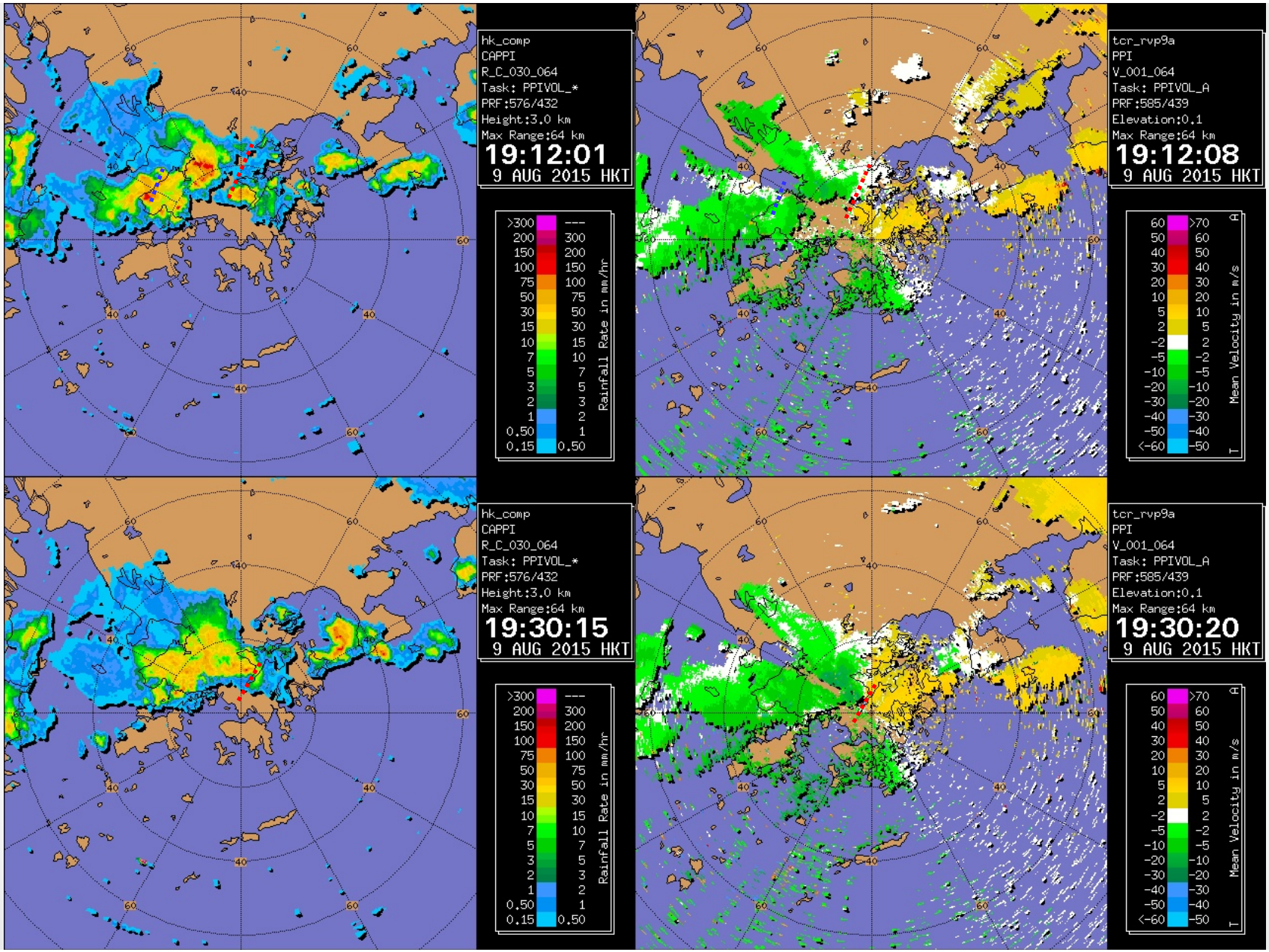

hk_comp
CAPPI
R_C_030_064
Task: PPIVOL_*
PRF:576/432
Height:3.0 km
Max Range:64 km
20:00:01
23 MAY 2015 HKT
>300 ---
200 300
150 200
100 150
75 100
50 75
30 50
15 30
10 15
7 10
5 7
3 5
2 3
1 2
0.50 1
0.15 0.50
Rainfall Rate in mm/hr
tms_rad1
PPI
V_000_064
Task: PPIVOL_A
PRF:576/432
Elevation:0.0
Max Range:64 km
20:00:01
23 MAY 2015 HKT
50 60
40 50
30 40
20 30
10 20
5 10
2 5
-2 2
-5 -2
-10 -5
-20 -10
-30 -20
-40 -30
-50 -40
-60 -50
Mean Velocity in m/s
A
T

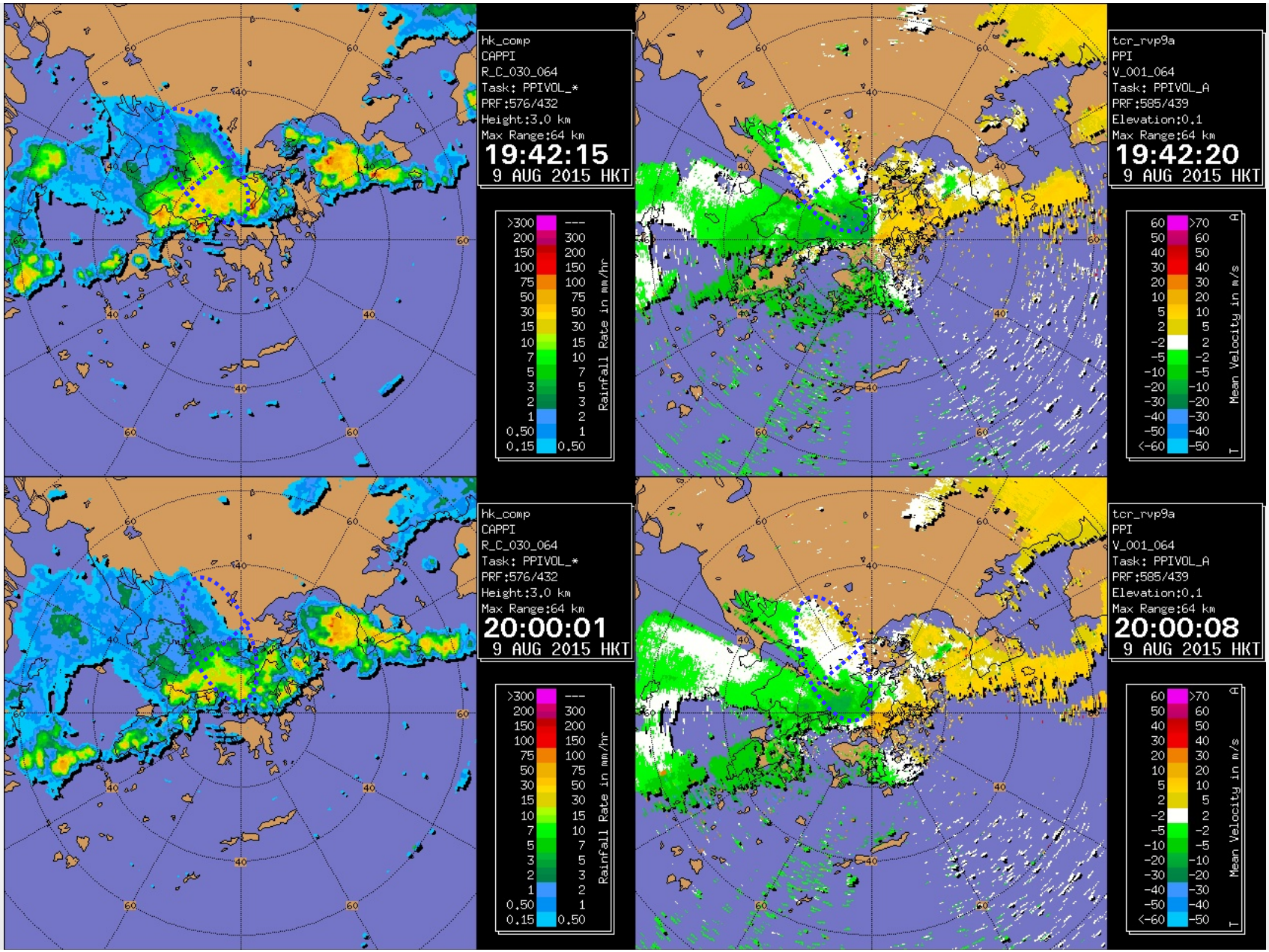
香港天文台
HONG KONG OBSERVATORY

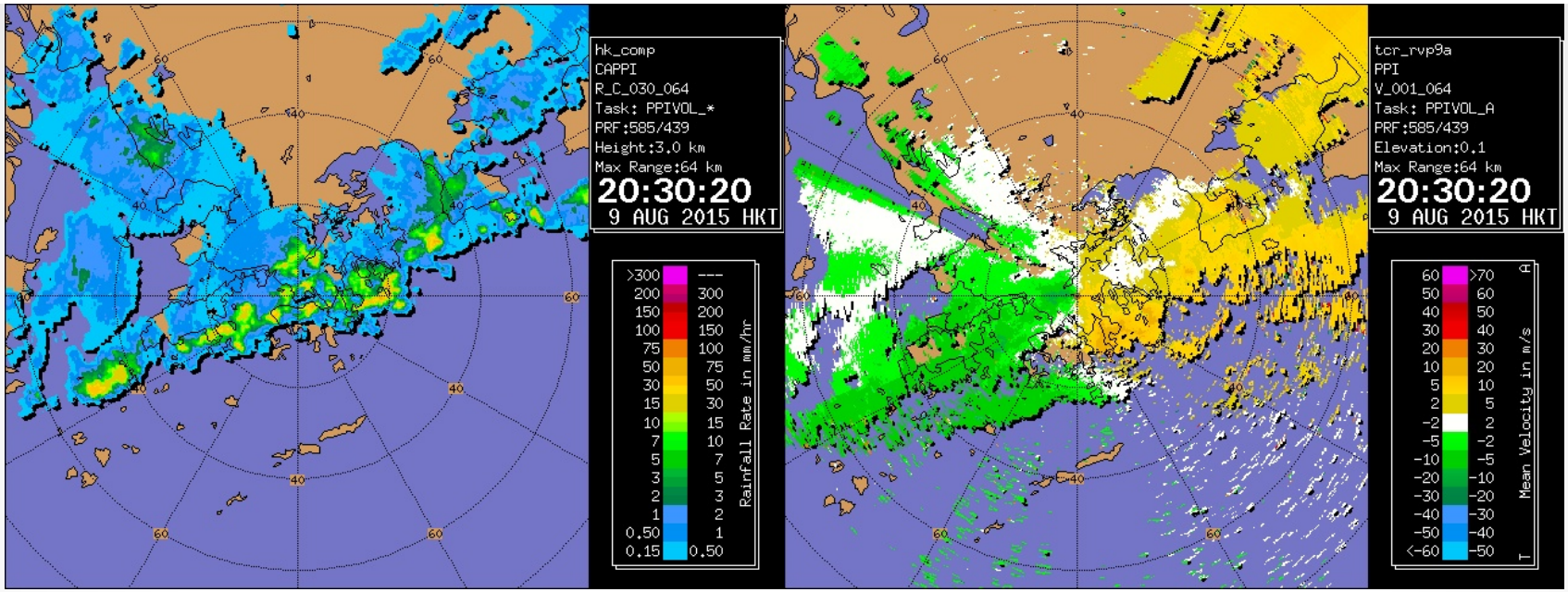
Case Study IV: 9 Aug 2015



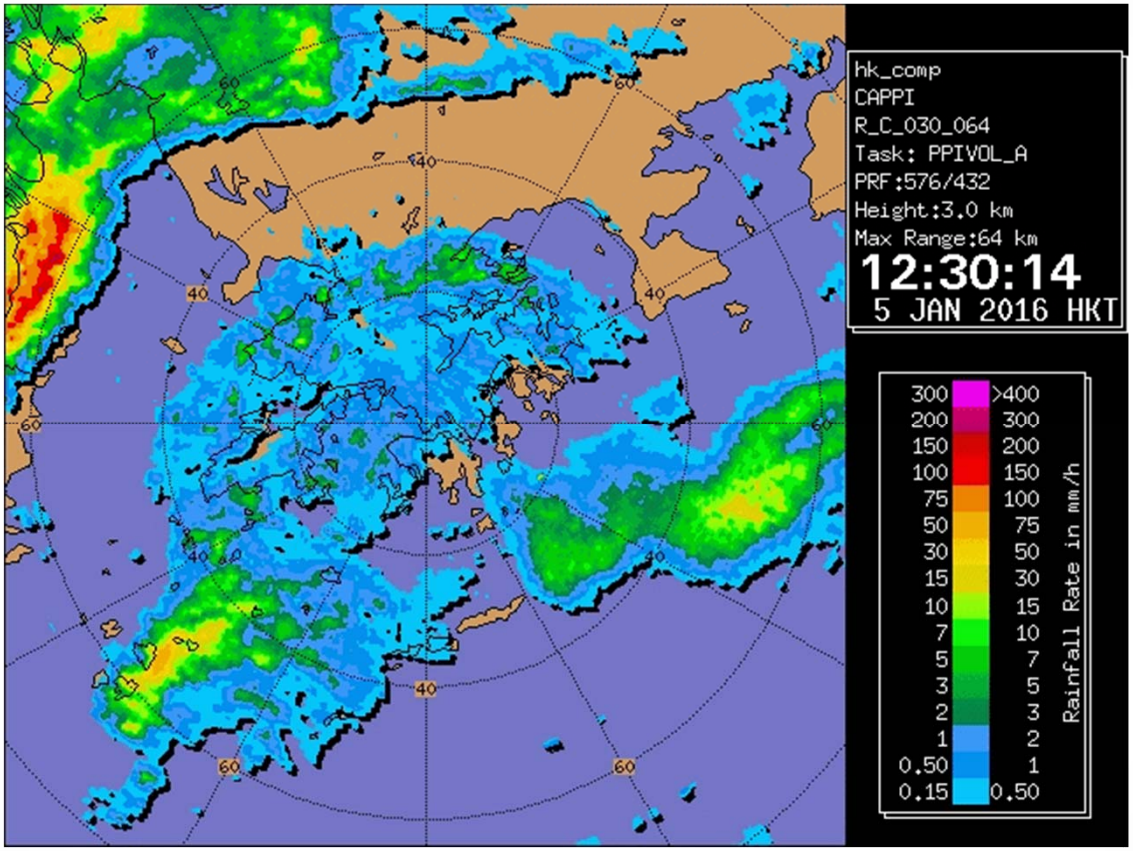

hk_comp
CAPPI
R_C_030_064
Task: PPIVOL_*
PRF:576/432
Height:3.0 km
Max Range:64 km
18:30:15
9 AUG 2015 HKT
>300 200 150 100 75 50 30 15 10 7 5 3 2 1 0.50 0.15
--- 300 200 150 100 75 50 30 15 10 7 5 3 2 1 0.50
Rainfall Rate in mm/hr
tcr_rvp9a
PPI
V_001_064
Task: PPIVOL_A
PRF:585/439
Elevation:0.1
Max Range:64 km
18:30:19
9 AUG 2015 HKT
60 50 40 30 20 10 5 2 -2 -5 -10 -20 -30 -40 -50 <-60
>70 60 50 40 30 20 10 5 -2 -5 -10 -20 -30 -40 -50
A
Mean Velocity in m/s
T
hk_comp
CAPPI
R_C_030_064
Task: PPIVOL_*
PRF:576/432
Height:3.0 km
Max Range:64 km
19:00:01
9 AUG 2015 HKT
>300 200 150 100 75 50 30 15 10 7 5 3 2 1 0.50 0.15
--- 300 200 150 100 75 50 30 15 10 7 5 3 2 1 0.50
Rainfall Rate in mm/hr
tcr_rvp9a
PPI
V_001_064
Task: PPIVOL_A
PRF:585/439
Elevation:0.1
Max Range:64 km
19:00:08
9 AUG 2015 HKT
60 50 40 30 20 10 5 2 -2 -5 -10 -20 -30 -40 -50 <-60
>70 60 50 40 30 20 10 5 -2 -5 -10 -20 -30 -40 -50
A
Mean Velocity in m/s
T

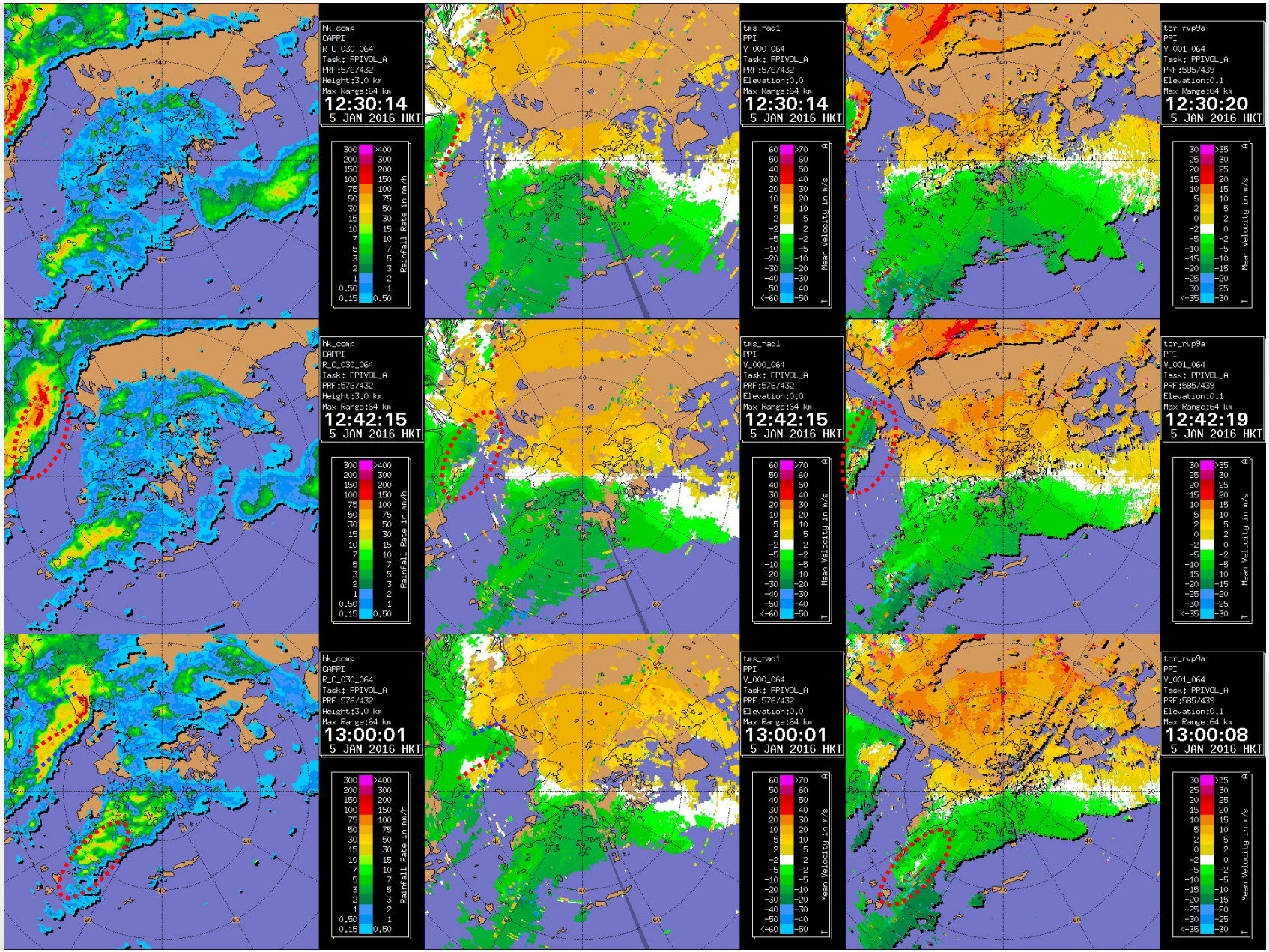

hk_comp
CAPPI
R_C_030_064
Task: PPIVOL_*
PRF:576/432
Height:3.0 km
Max Range:64 km
19:12:01
9 AUG 2015 HKT
>300 200 150 100 75 50 30 15 10 7 5 3 2 1 0.50 0.15
--- 300 200 150 100 75 50 30 15 10 7 5 3 2 1 0.50
Rainfall Rate in mm/hr
tcr_rvp9a
PPI
V_001_064
Task: PPIVOL_A
PRF:585/439
Elevation:0.1
Max Range:64 km
19:12:08
9 AUG 2015 HKT
60 50 40 30 20 10 5 2 -2 -5 -10 -20 -30 -40 -50 <-60
>70 60 50 40 30 20 10 5 2 -2 -5 -10 -20 -30 -40 -50
Mean Velocity in m/s
hk_comp
CAPPI
R_C_030_064
Task: PPIVOL_*
PRF:576/432
Height:3.0 km
Max Range:64 km
19:30:15
9 AUG 2015 HKT
>300 200 150 100 75 50 30 15 10 7 5 3 2 1 0.50 0.15
--- 300 200 150 100 75 50 30 15 10 7 5 3 2 1 0.50
Rainfall Rate in mm/hr
tcr_rvp9a
PPI
V_001_064
Task: PPIVOL_A
PRF:585/439
Elevation:0.1
Max Range:64 km
19:30:20
9 AUG 2015 HKT
60 50 40 30 20 10 5 2 -2 -5 -10 -20 -30 -40 -50 <-60
>70 60 50 40 30 20 10 5 2 -2 -5 -10 -20 -30 -40 -50
Mean Velocity in m/s

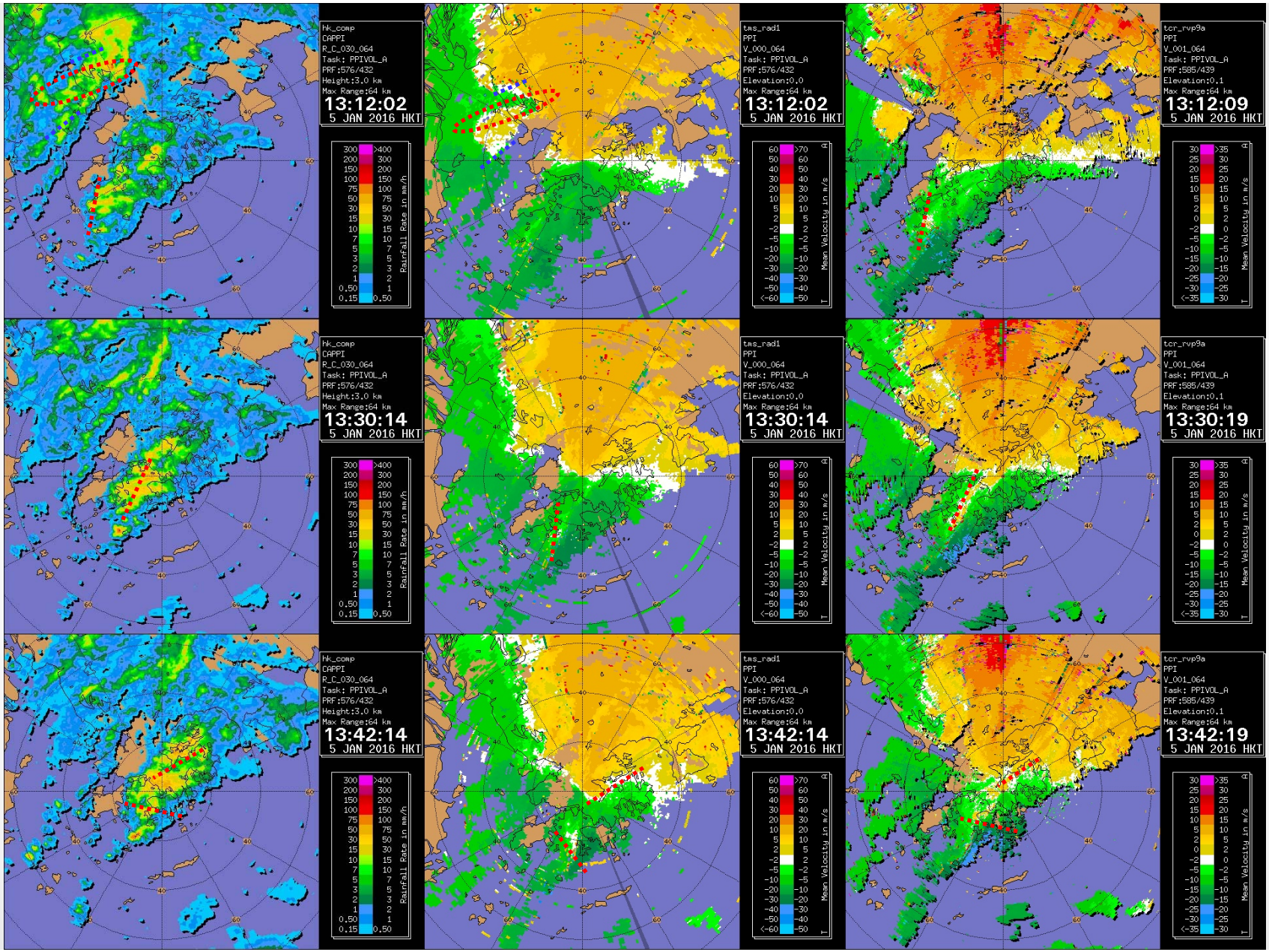

hk_comp
CAPPI
R_C_030_064
Task: PPIVOL_*
PRF:576/432
Height:3.0 km
Max Range:64 km
19:42:15
9 AUG 2015 HKT
Rainfall Rate in mm/hr
tcr_rvp9a
PPI
V_001_064
Task: PPIVOL_A
PRF:585/439
Elevation:0.1
Max Range:64 km
19:42:20
9 AUG 2015 HKT
Mean Velocity in m/s
hk_comp
CAPPI
R_C_030_064
Task: PPIVOL_*
PRF:576/432
Height:3.0 km
Max Range:64 km
20:00:01
9 AUG 2015 HKT
Rainfall Rate in mm/hr
tcr_rvp9a
PPI
V_001_064
Task: PPIVOL_A
PRF:585/439
Elevation:0.1
Max Range:64 km
20:00:08
9 AUG 2015 HKT
Mean Velocity in m/s

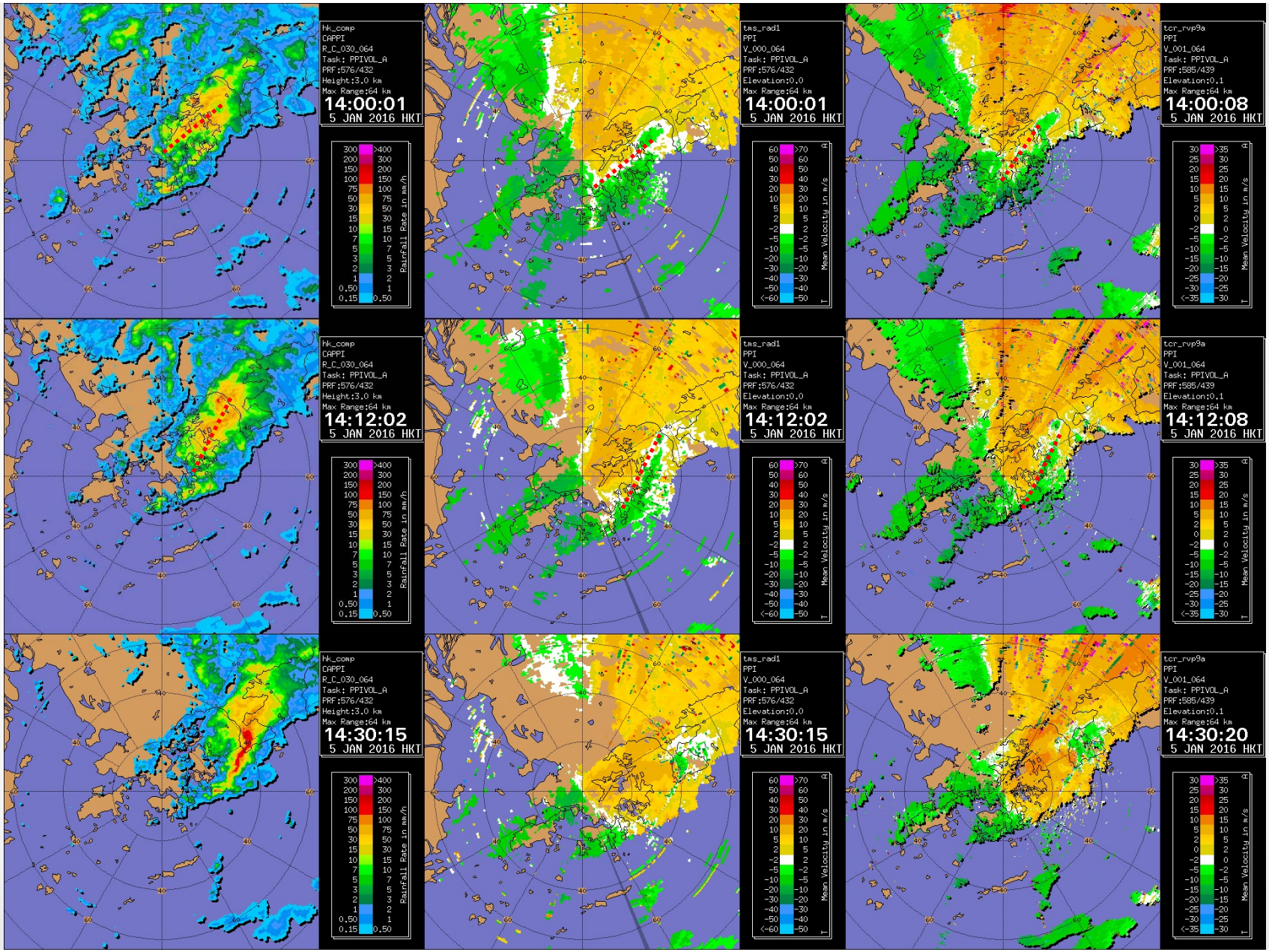

hk_comp
CAPPI
R_C_030_064
Task: PPIVOL_*
PRF:585/439
Height:3.0 km
Max Range:64 km
20:30:20
9 AUG 2015 HKT
>300 ---
200 300
150 200
100 150
75 100
50 75
30 50
15 30
10 15
7 10
5 7
3 5
2 3
1 2
0.50 1
0.15 0.50
Rainfall Rate in mm/hr
tcr_rvp9a
PPI
V_001_064
Task: PPIVOL_A
PRF:585/439
Elevation:0.1
Max Range:64 km
20:30:20
9 AUG 2015 HKT
60 >70
50 60
40 50
30 40
20 30
10 20
5 10
2 5
-2 2
-5 -2
-10 -5
-20 -10
-30 -20
-40 -30
-50 -40
<-60 -50
Mean Velocity in m/s
A
T

Case Study V: 5 Jan 2016




hk_comp
CAPPI
R_C_030_064
Task: PPIVOL_A
PRF:576/432
Height:3.0 km
Max Range:64 km
12:30:14
5 JAN 2016 HKT
Rainfall Rate in mm/h
tms_rad1
PPI
V_000_064
Task: PPIVOL_A
PRF:576/432
Elevation:0.0
Max Range:64 km
12:30:14
5 JAN 2016 HKT
Mean Velocity in m/s
tcr_rvp9a
PPI
V_001_064
Task: PPIVOL_A
PRF:585/439
Elevation:0.1
Max Range:64 km
12:30:20
5 JAN 2016 HKT
Mean Velocity in m/s
hk_comp
CAPPI
R_C_030_064
Task: PPIVOL_A
PRF:576/432
Height:3.0 km
Max Range:64 km
12:42:15
5 JAN 2016 HKT
Rainfall Rate in mm/h
tms_rad1
PPI
V_000_064
Task: PPIVOL_A
PRF:576/432
Elevation:0.0
Max Range:64 km
12:42:15
5 JAN 2016 HKT
Mean Velocity in m/s
tcr_rvp9a
PPI
V_001_064
Task: PPIVOL_A
PRF:585/439
Elevation:0.1
Max Range:64 km
12:42:19
5 JAN 2016 HKT
Mean Velocity in m/s
hk_comp
CAPPI
R_C_030_064
Task: PPIVOL_A
PRF:576/432
Height:3.0 km
Max Range:64 km
13:00:01
5 JAN 2016 HKT
Rainfall Rate in mm/h
tms_rad1
PPI
V_000_064
Task: PPIVOL_A
PRF:576/432
Elevation:0.0
Max Range:64 km
13:00:01
5 JAN 2016 HKT
Mean Velocity in m/s
tcr_rvp9a
PPI
V_001_064
Task: PPIVOL_A
PRF:585/439
Elevation:0.1
Max Range:64 km
13:00:08
5 JAN 2016 HKT
Mean Velocity in m/s


hk_comp
CAPPI
R_C_030_064
Task: PPIVOL_A
PRF:576/432
Height:3.0 km
Max Range:64 km
13:12:02
5 JAN 2016 HKT
Rainfall Rate in mm/h
tms_rad1
PPI
V_000_064
Task: PPIVOL_A
PRF:576/432
Elevation:0.0
Max Range:64 km
13:12:02
5 JAN 2016 HKT
Mean Velocity in m/s
tcr_rvp9a
PPI
V_001_064
Task: PPIVOL_A
PRF:585/439
Elevation:0.1
Max Range:64 km
13:12:09
5 JAN 2016 HKT
Mean Velocity in m/s
hk_comp
CAPPI
R_C_030_064
Task: PPIVOL_A
PRF:576/432
Height:3.0 km
Max Range:64 km
13:30:14
5 JAN 2016 HKT
Rainfall Rate in mm/h
tms_rad1
PPI
V_000_064
Task: PPIVOL_A
PRF:576/432
Elevation:0.0
Max Range:64 km
13:30:14
5 JAN 2016 HKT
Mean Velocity in m/s
tcr_rvp9a
PPI
V_001_064
Task: PPIVOL_A
PRF:585/439
Elevation:0.1
Max Range:64 km
13:30:19
5 JAN 2016 HKT
Mean Velocity in m/s
hk_comp
CAPPI
R_C_030_064
Task: PPIVOL_A
PRF:576/432
Height:3.0 km
Max Range:64 km
13:42:14
5 JAN 2016 HKT
Rainfall Rate in mm/h
tms_rad1
PPI
V_000_064
Task: PPIVOL_A
PRF:576/432
Elevation:0.0
Max Range:64 km
13:42:14
5 JAN 2016 HKT
Mean Velocity in m/s
tcr_rvp9a
PPI
V_001_064
Task: PPIVOL_A
PRF:585/439
Elevation:0.1
Max Range:64 km
13:42:19
5 JAN 2016 HKT
Mean Velocity in m/s

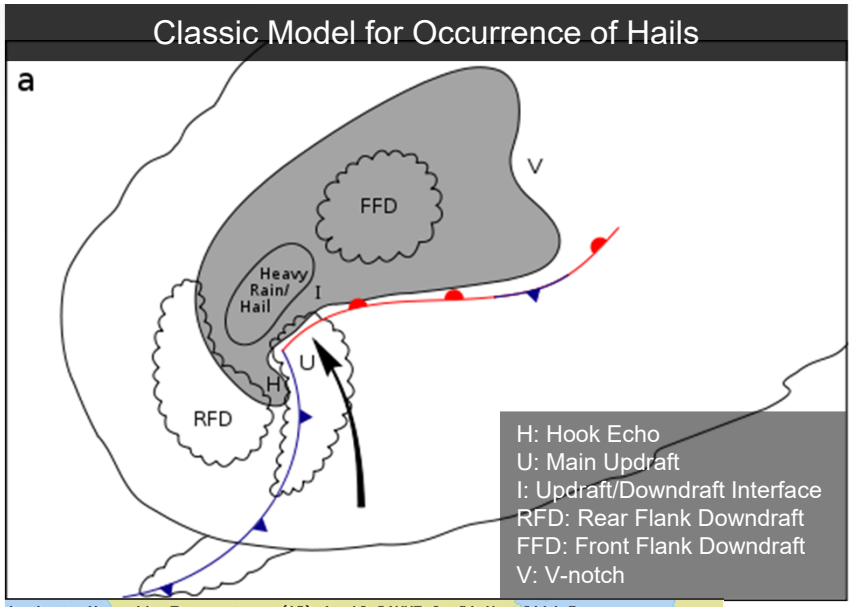

hk_comp
CAPPI
R_C_030_064
Task: PPIVOL_A
PRF:576/432
Height:3.0 km
Max Range:64 km
14:00:01
5 JAN 2016 HKT
Rainfall Rate in mm/h
tms_rad1
PPI
V_000_064
Task: PPIVOL_A
PRF:576/432
Elevation:0.0
Max Range:64 km
14:00:01
5 JAN 2016 HKT
Mean Velocity in m/s
tcr_rvp9a
PPI
V_001_064
Task: PPIVOL_A
PRF:585/439
Elevation:0.1
Max Range:64 km
14:00:08
5 JAN 2016 HKT
Mean Velocity in m/s
hk_comp
CAPPI
R_C_030_064
Task: PPIVOL_A
PRF:576/432
Height:3.0 km
Max Range:64 km
14:12:02
5 JAN 2016 HKT
Rainfall Rate in mm/h
tms_rad1
PPI
V_000_064
Task: PPIVOL_A
PRF:576/432
Elevation:0.0
Max Range:64 km
14:12:02
5 JAN 2016 HKT
Mean Velocity in m/s
tcr_rvp9a
PPI
V_001_064
Task: PPIVOL_A
PRF:585/439
Elevation:0.1
Max Range:64 km
14:12:08
5 JAN 2016 HKT
Mean Velocity in m/s
hk_comp
CAPPI
R_C_030_064
Task: PPIVOL_A
PRF:576/432
Height:3.0 km
Max Range:64 km
14:30:15
5 JAN 2016 HKT
Rainfall Rate in mm/h
tms_rad1
PPI
V_000_064
Task: PPIVOL_A
PRF:576/432
Elevation:0.0
Max Range:64 km
14:30:15
5 JAN 2016 HKT
Mean Velocity in m/s
tcr_rvp9a
PPI
V_001_064
Task: PPIVOL_A
PRF:585/439
Elevation:0.1
Max Range:64 km
14:30:20
5 JAN 2016 HKT
Mean Velocity in m/s

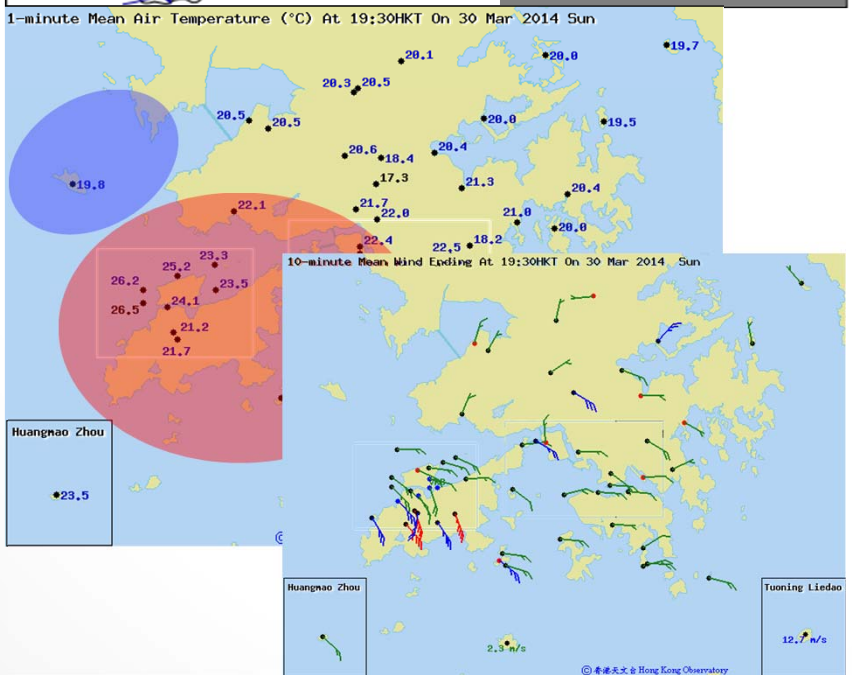
香港天文台
HONG KONG OBSERVATORY

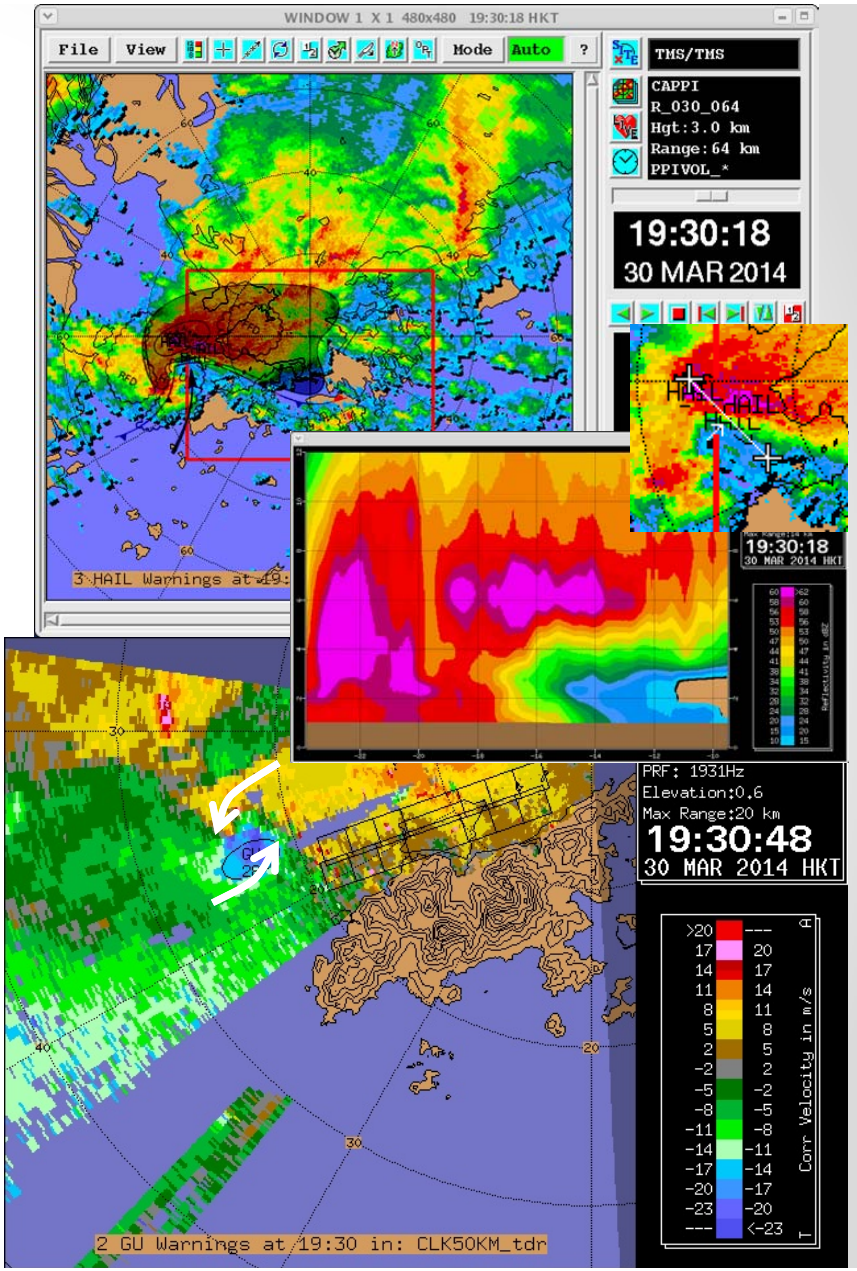
Hail

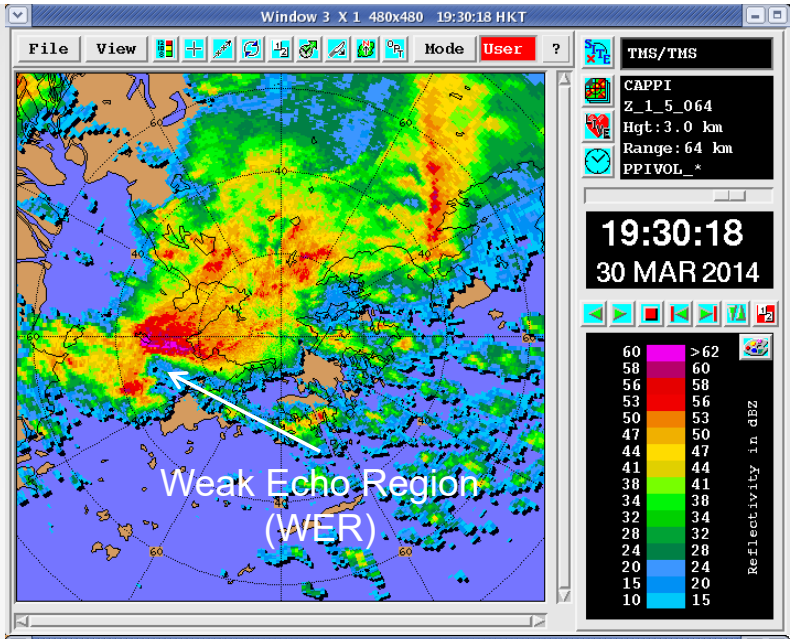
Hail Signatures on Radar

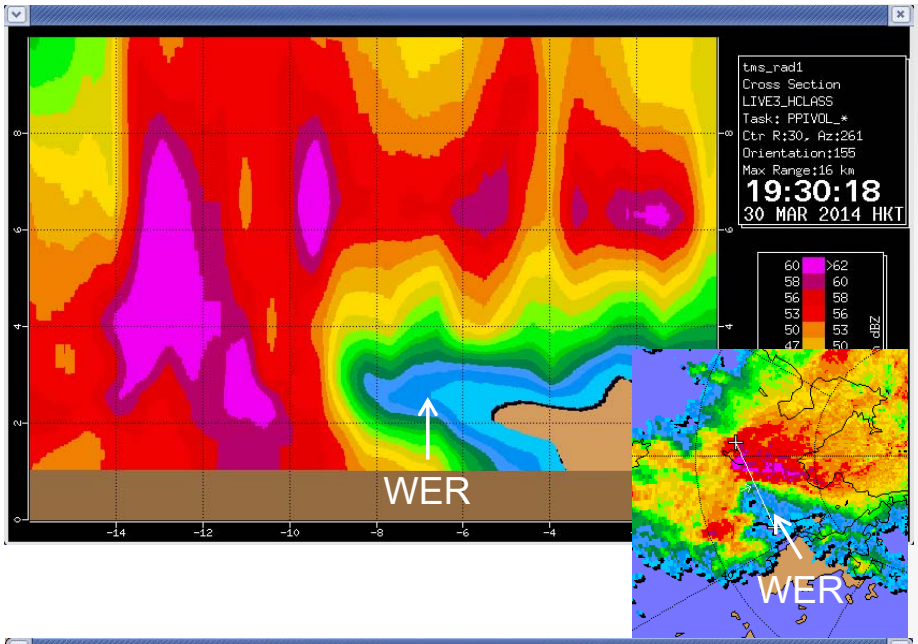
1. Hook echo
2. Overhang echo
3. High reflectivity (Core reflectivity > 58 dBZ)
4. Low-level convergence or mesocyclone
5. Rain-hail mixture in hydrometeor classification

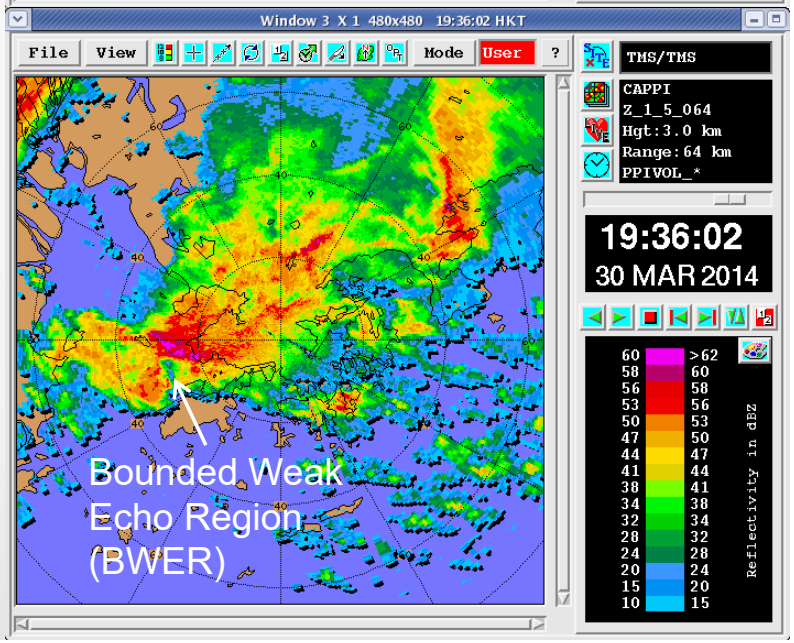


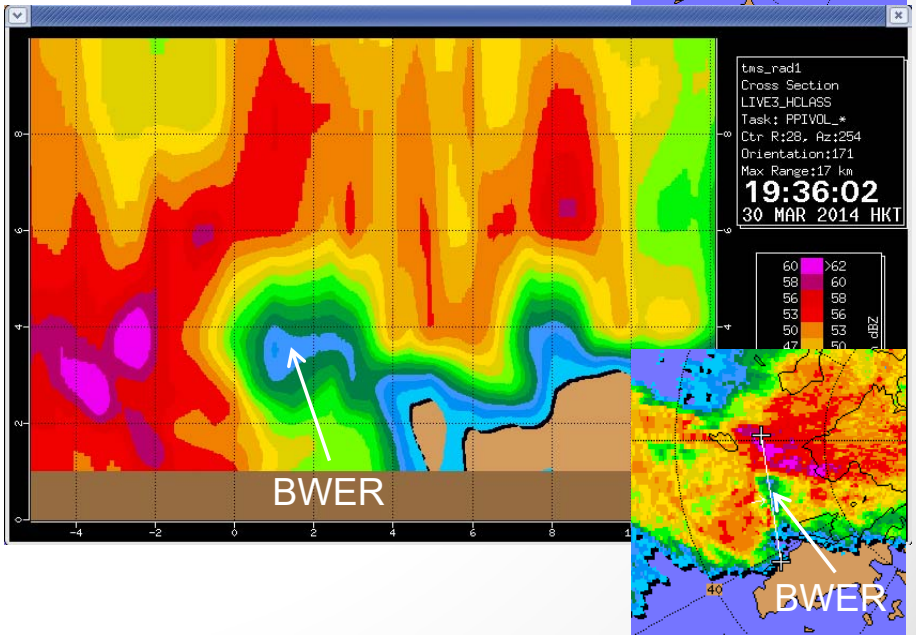




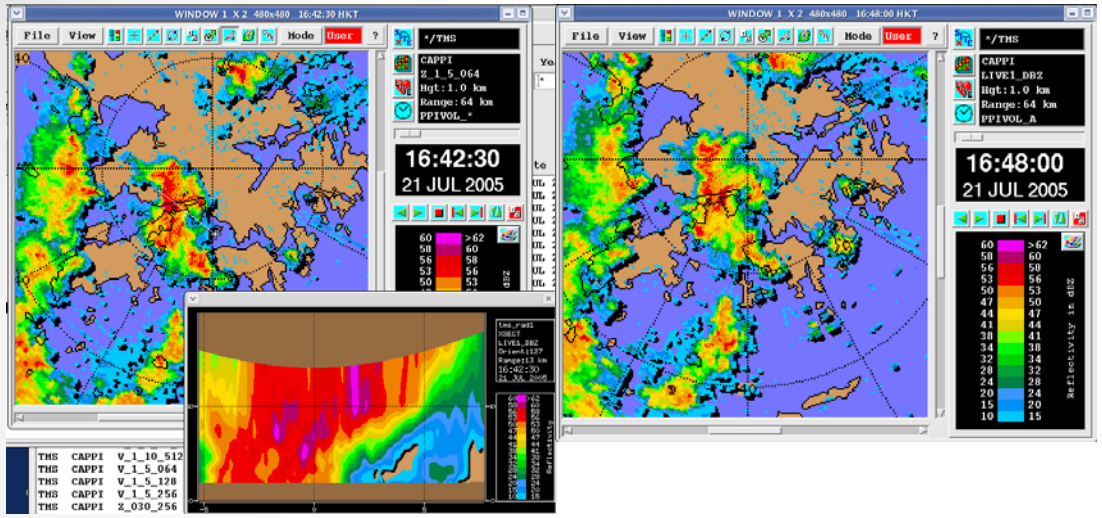

Window 3 X 1 480x480 19:30:18 HKT
File
View
Mode
User
?
TMS/TMS
CAPPI
Z_1_5_064
Hgt:3.0 km
Range:64 km
PPIVOL_*
19:30:18
30 MAR 2014
Reflectivity in dBZ
Weak Echo Region
(WER)

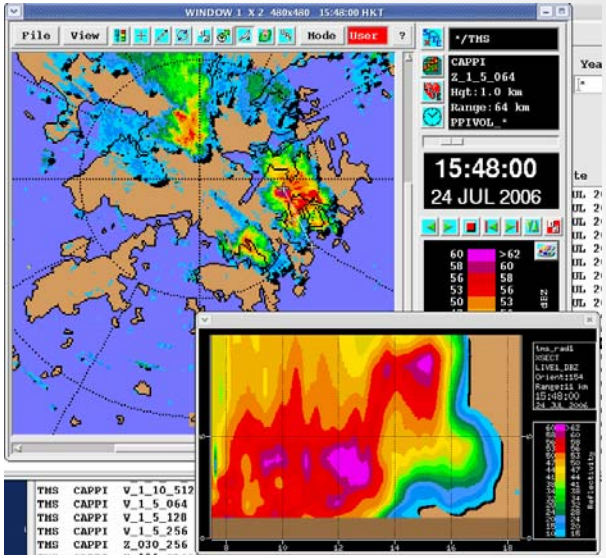

tms_rad1
Cross Section
LIVE3_HCLASS
Task: PPIVOL_*
Ctr R:30, Az:261
Orientation:155
Max Range:16 km
19:30:18
30 MAR 2014 HKT
dBZ
WER
WER

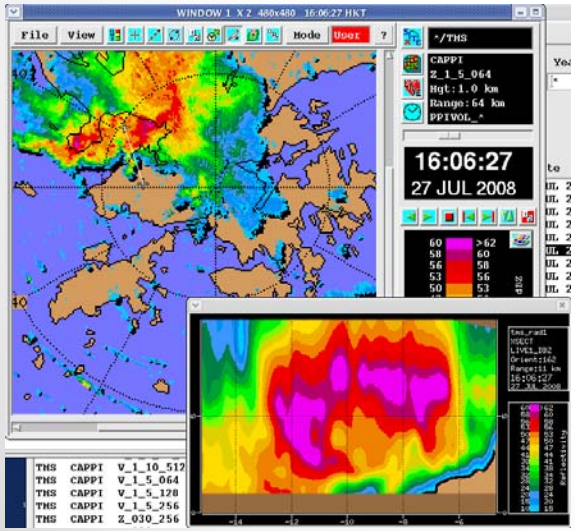

Window 3 X 1 480x480 19:36:02 HKT
File
View
Mode
User
?
TMS/TMS
CAPPI
Z_1_5_064
Hgt:3.0 km
Range:64 km
PPIVOL_*
19:36:02
30 MAR 2014
Reflectivity in dBZ
Bounded Weak
Echo Region
(BWER)

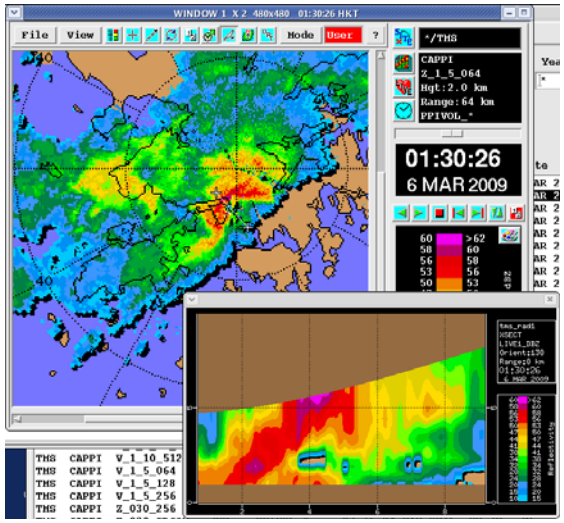

tms_rad1
Cross Section
LIVE3_HCLASS
Task: PPIVOL_*
Ctr R:28, Az:254
Orientation:171
Max Range:17 km
19:36:02
30 MAR 2014 HKT
dBZ
BWER
BWER

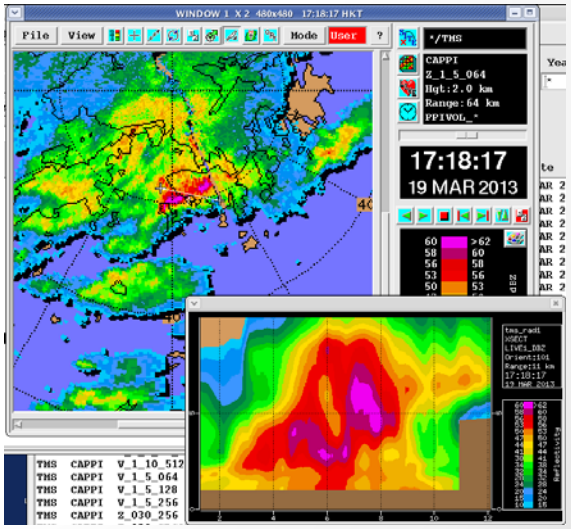
Past Hail Events





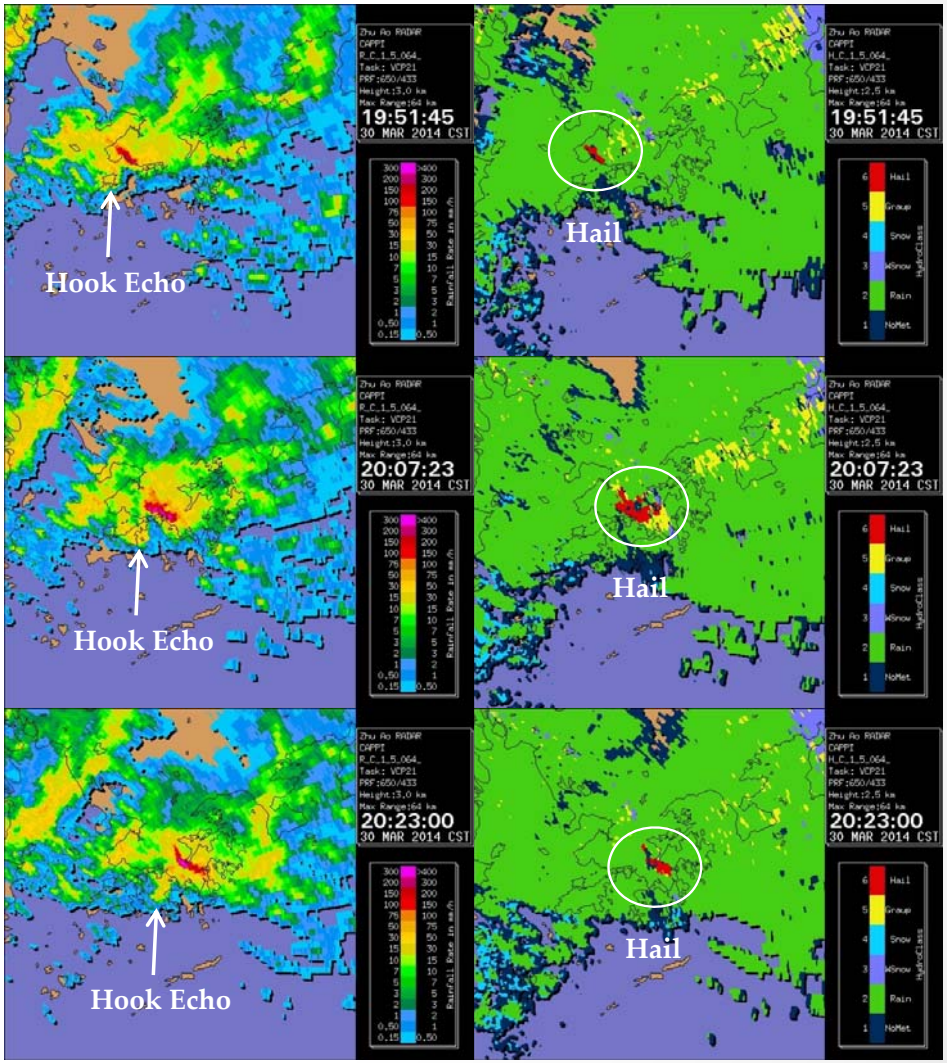


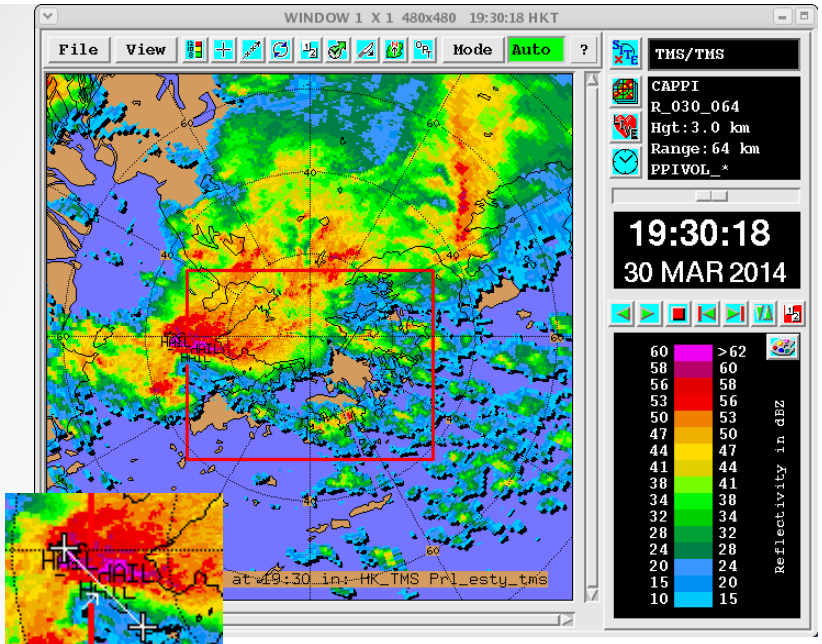


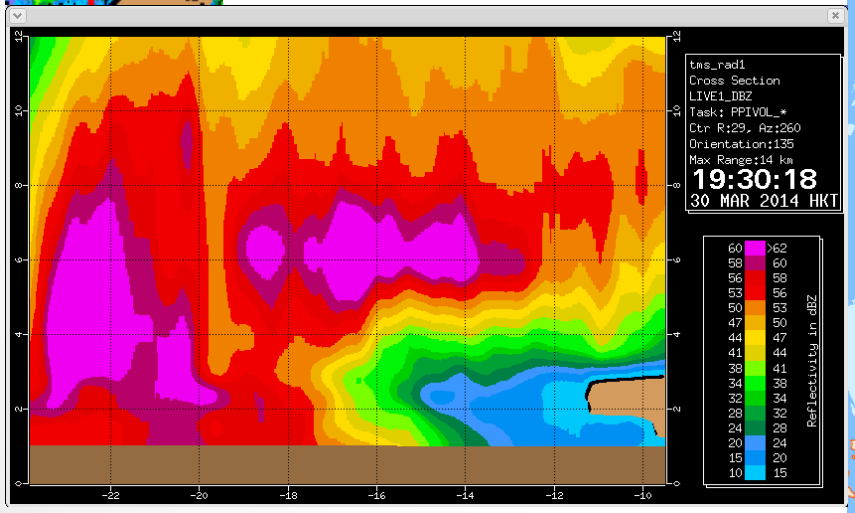


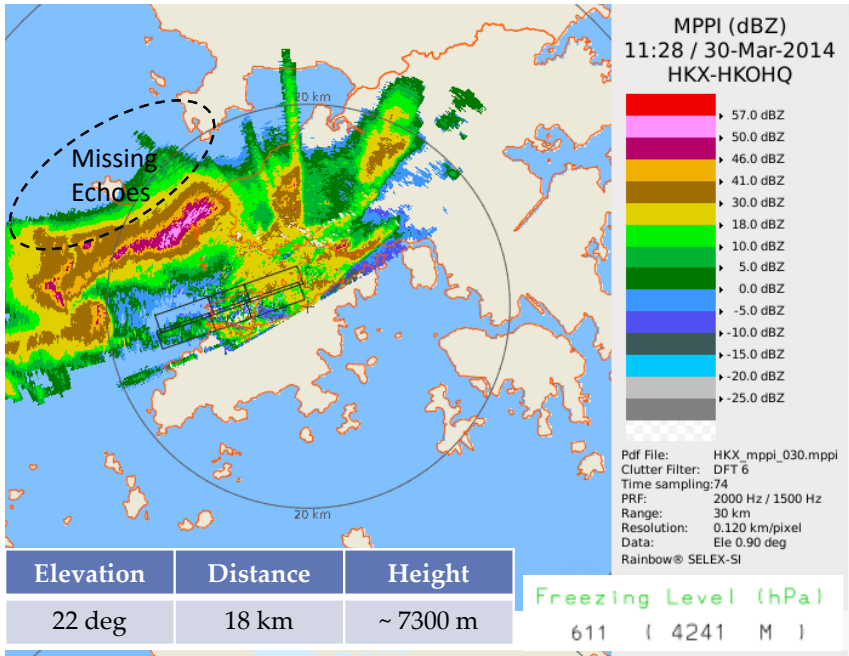
Hydrometeor Classification of Dual-pol Radar

30 March 2014, hail report received by HKO



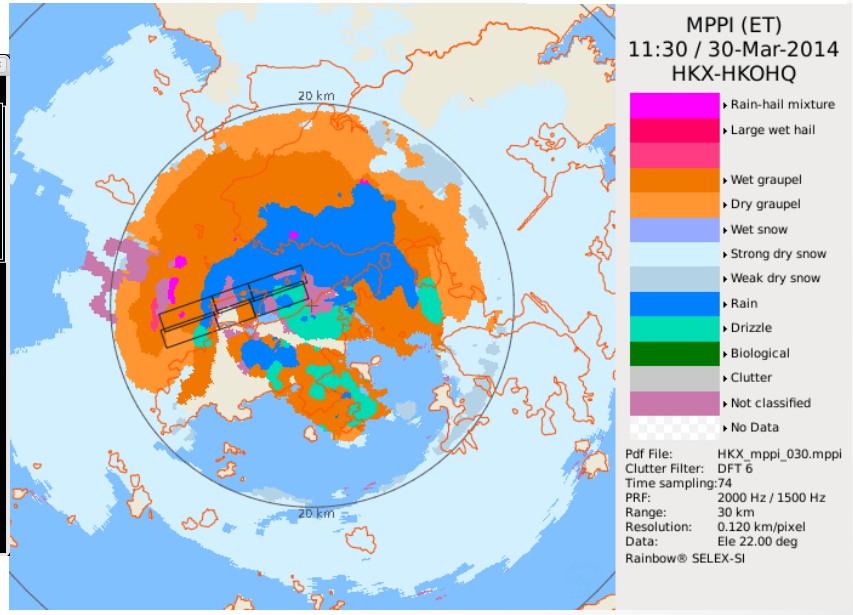






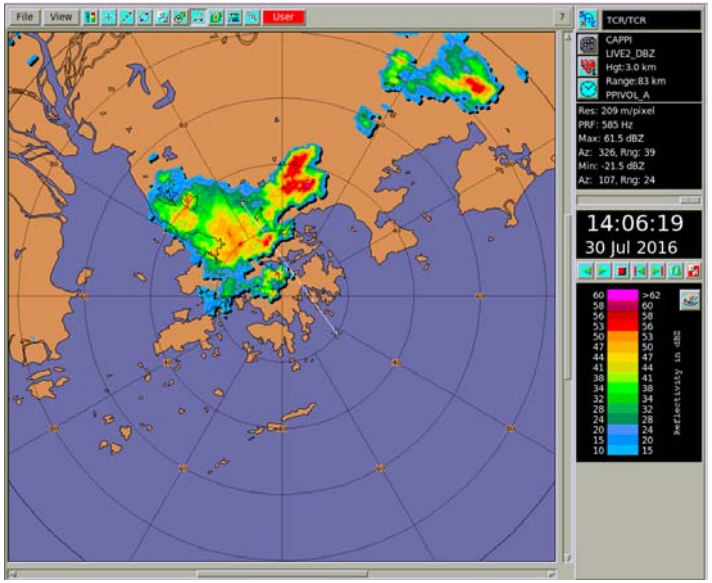
Elevation	Distance	Height
22 deg	18 km	~ 7300 m

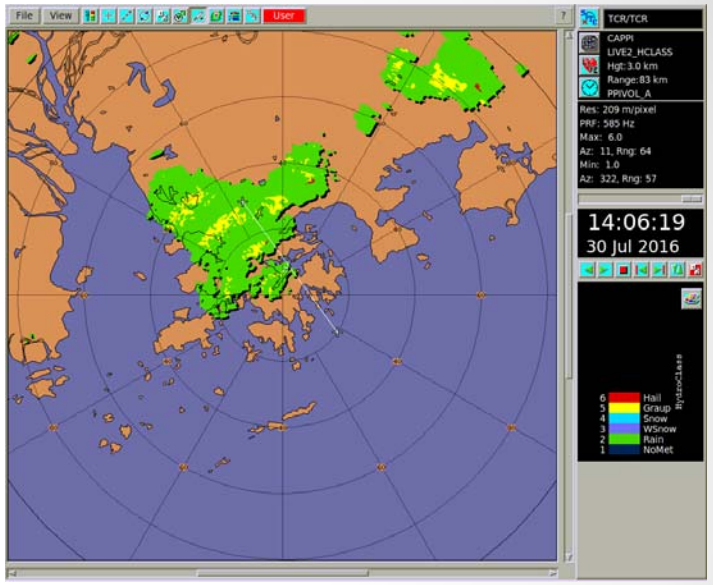
Freezing Level (hPa)
611 (4241 M)

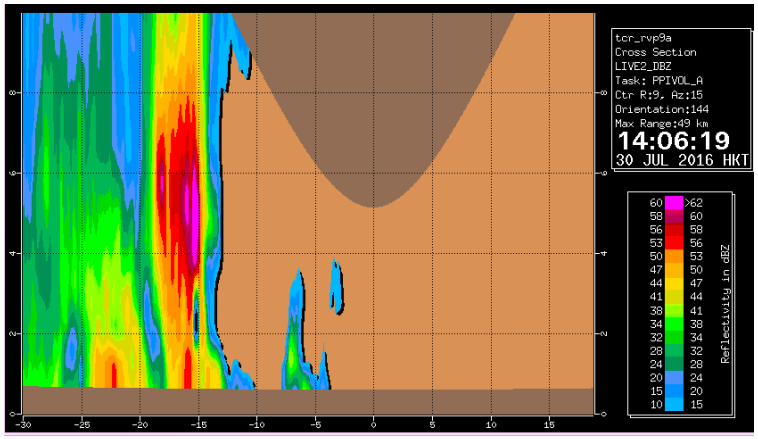


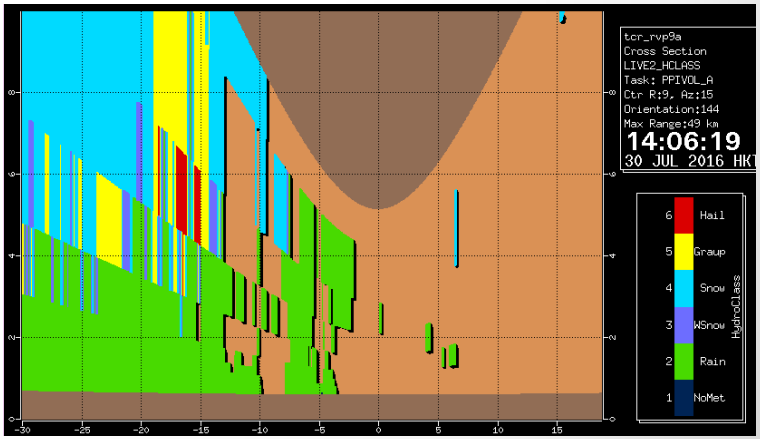
Hail at around on 30 July 2016

Hail was reported at Tai Po during the passage of the thunderstorms on 30 July 2016







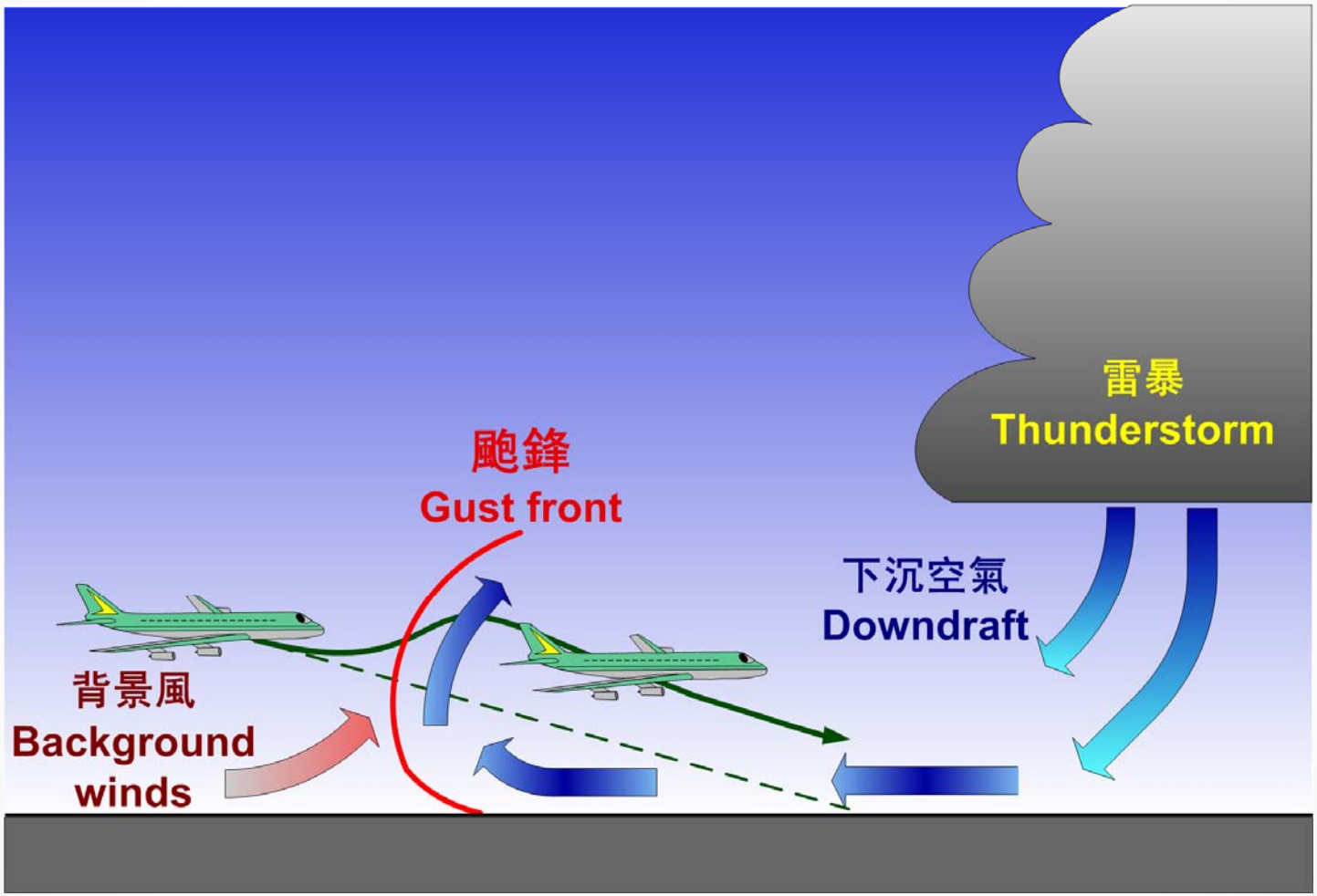


香港天文台
HONG KONG OBSERVATORY

Gust Front and Downbursts

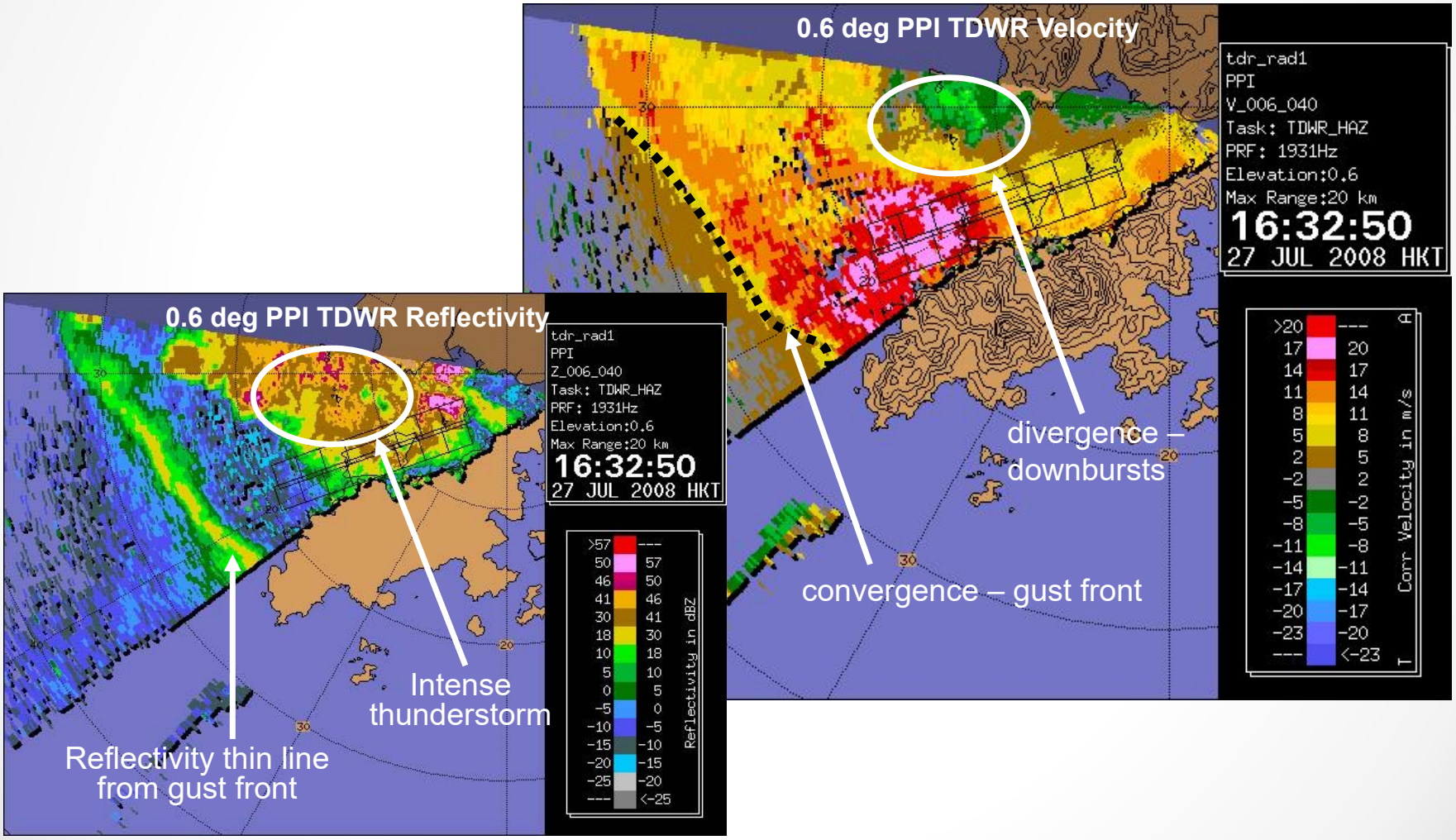
香港天文台
HONG KONG OBSERVATORY

Downbursts and Gust Front associated with thunderstorms



香港天文台
HONG KONG OBSERVATORY

- Downbursts (microbursts) and Gust Front associated with thunderstorms observed on TDWR



Content

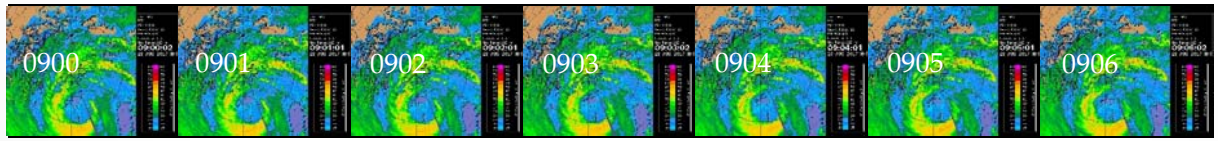
- Radar QPE
- Dual-polarization Weather Radar
- Interpretation of Extreme Weather on Radar Imagery
- Other Possible Scanning Strategy – 1-min Rapid Scan

Operational benefits I - Timeliness

	Normal Volume Scan	1-min Rapid Scan
Update Frequency	Once every 6-minute	Once every 1 minute

Volume Scan

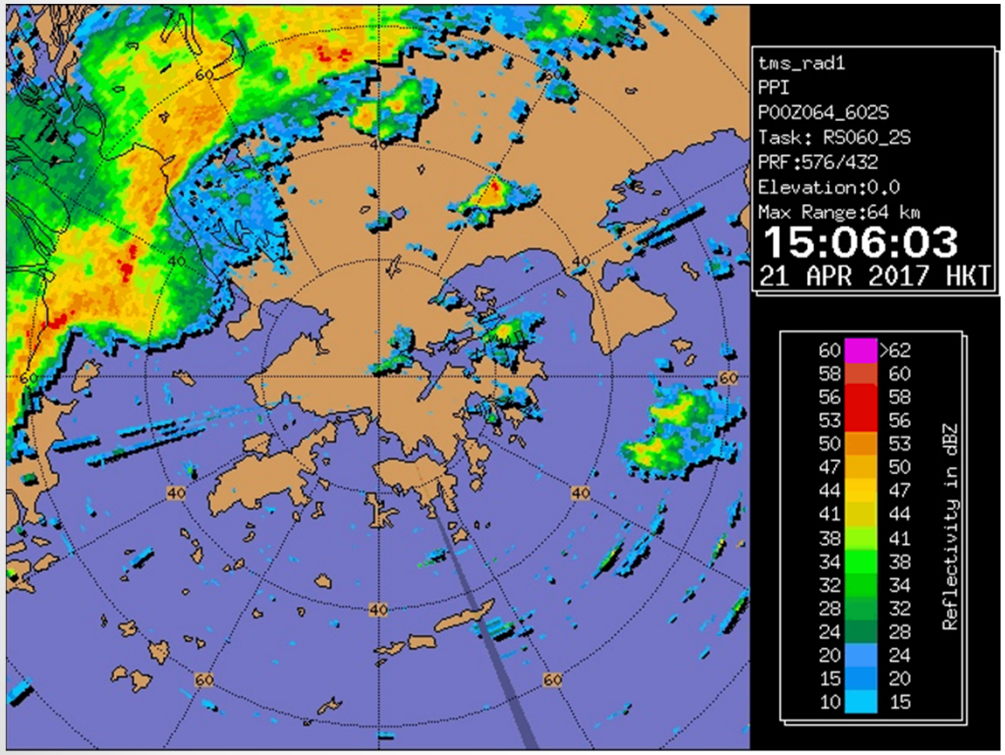
Rapid Scan



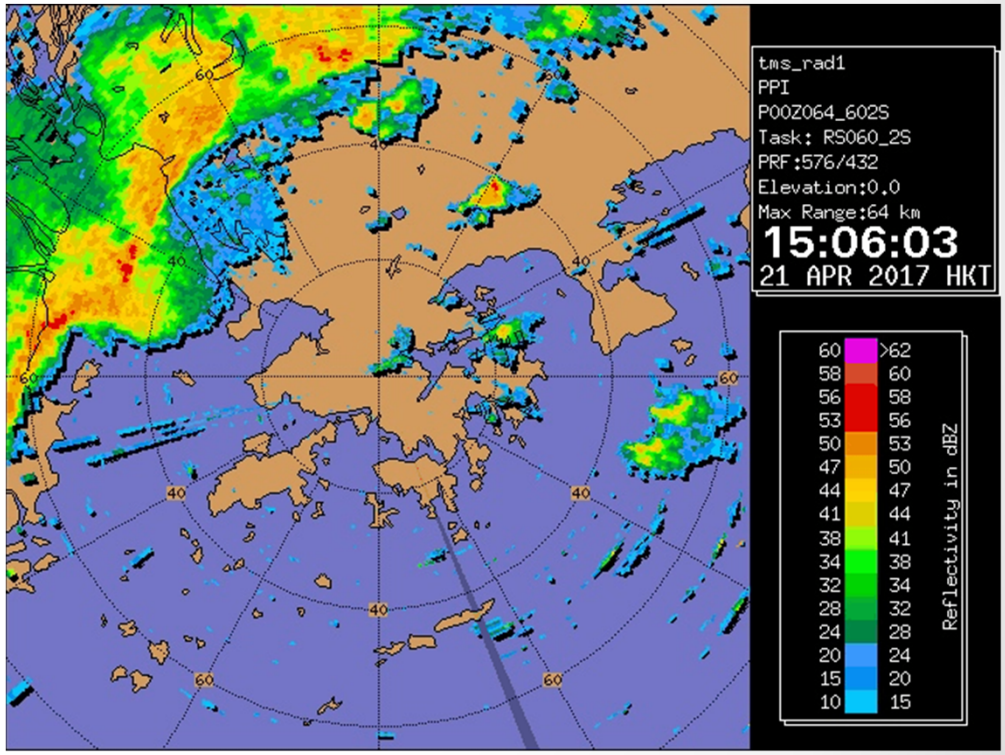
Lead time 0-min | Lead time 1-min | Lead time 2-min | Lead time 3-min | Lead time 4-min | Lead time 5-min | Lead time 0-min

Operational benefits II – Better Continuity

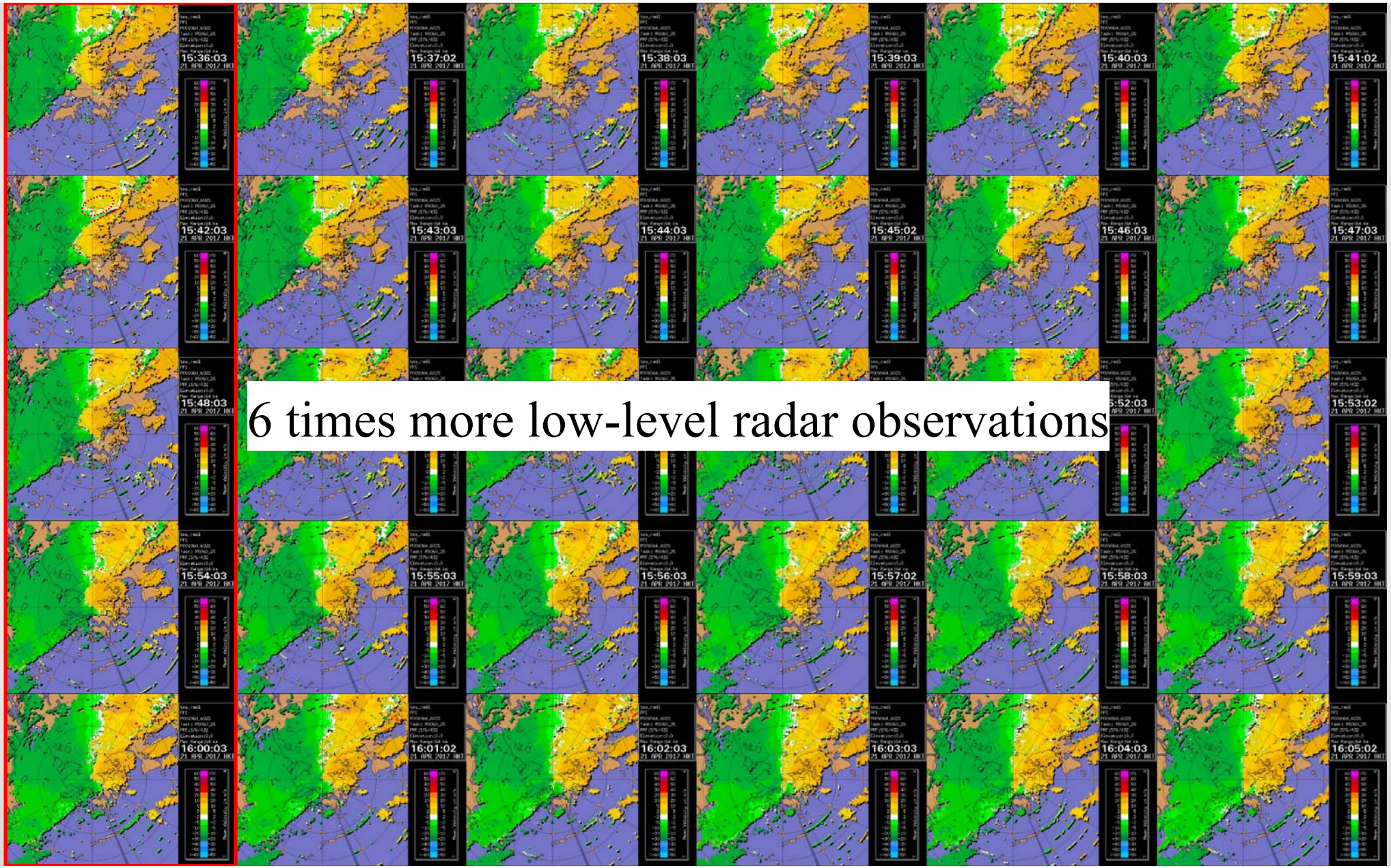
- Better display of echo evolution in 1-min rapid scan



6-min radar
imagery animation

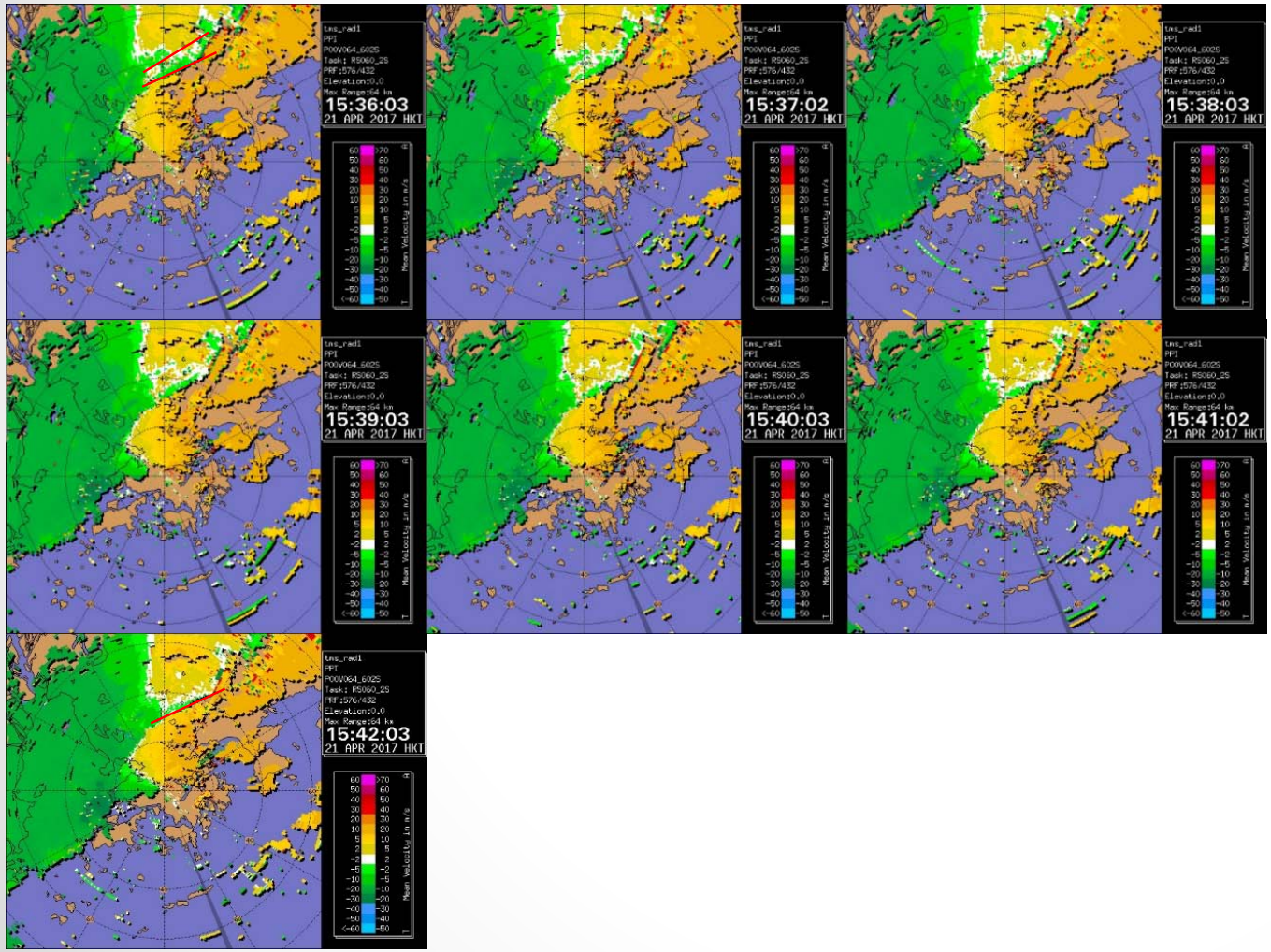


1-min radar
imagery animation


15:36:03
15:37:02
15:38:03
15:39:03
15:40:03
15:41:02
15:42:03
15:43:03
15:44:03
15:45:02
15:46:03
15:47:03
15:48:03
15:53:02
15:54:03
15:55:03
15:56:03
15:57:02
15:58:03
15:59:03
16:00:03
16:01:02
16:02:03
16:03:03
16:04:03
16:05:02
6 times more low-level radar observations

香港天文台
HONG KONG OBSERVATORY

Enhanced observations I - Low-level convergence



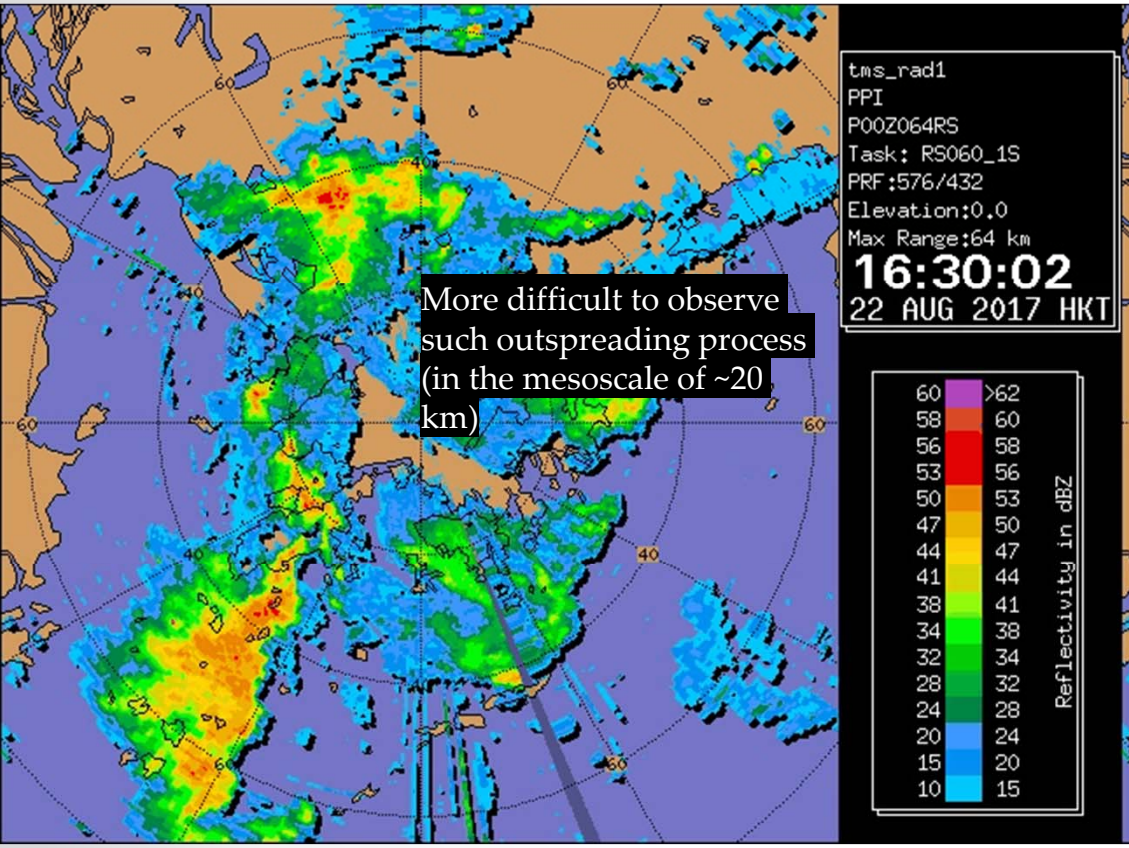
Three possible scenarios:

(i) the two convergence lines have merged into one; or

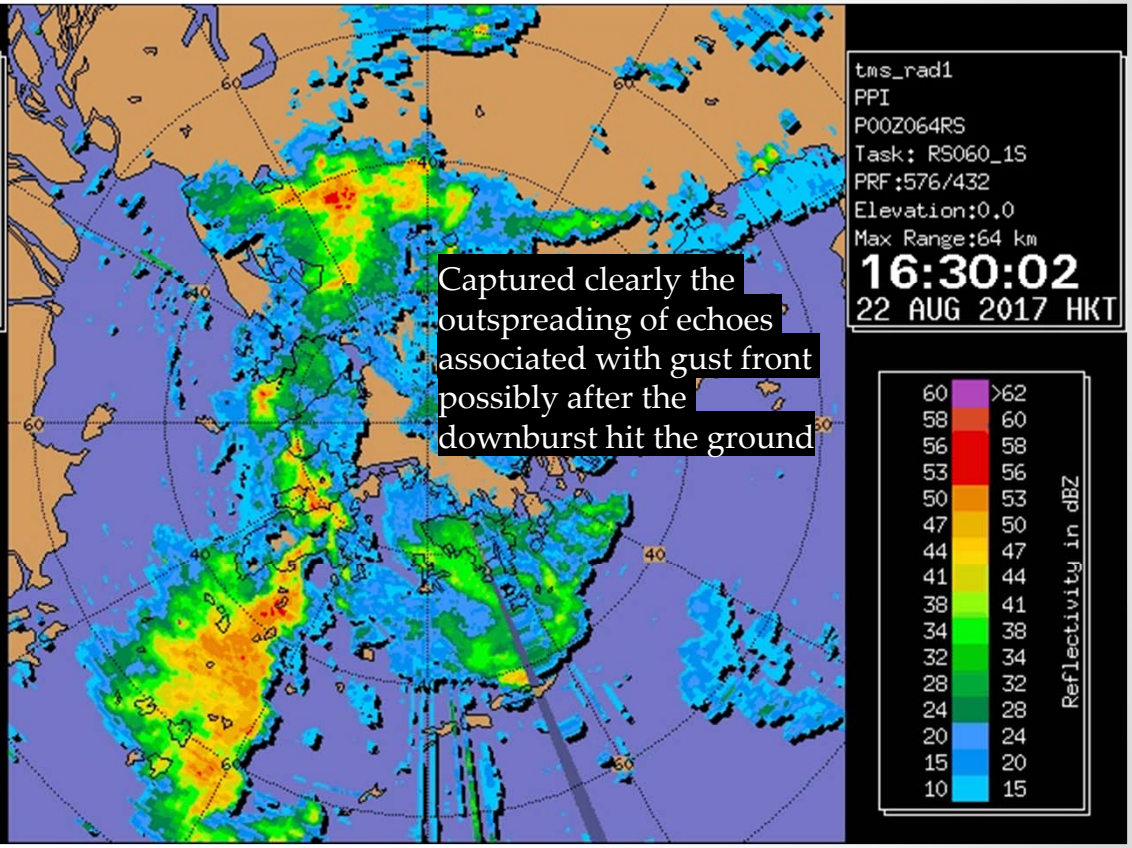
(ii) the convergence line further north dissipated while the one to its south persisted and moved slowly; or

(iii) the convergence line further north persisted and moved slowly while the one to its south dissipated.

Enhanced observations II - Downburst

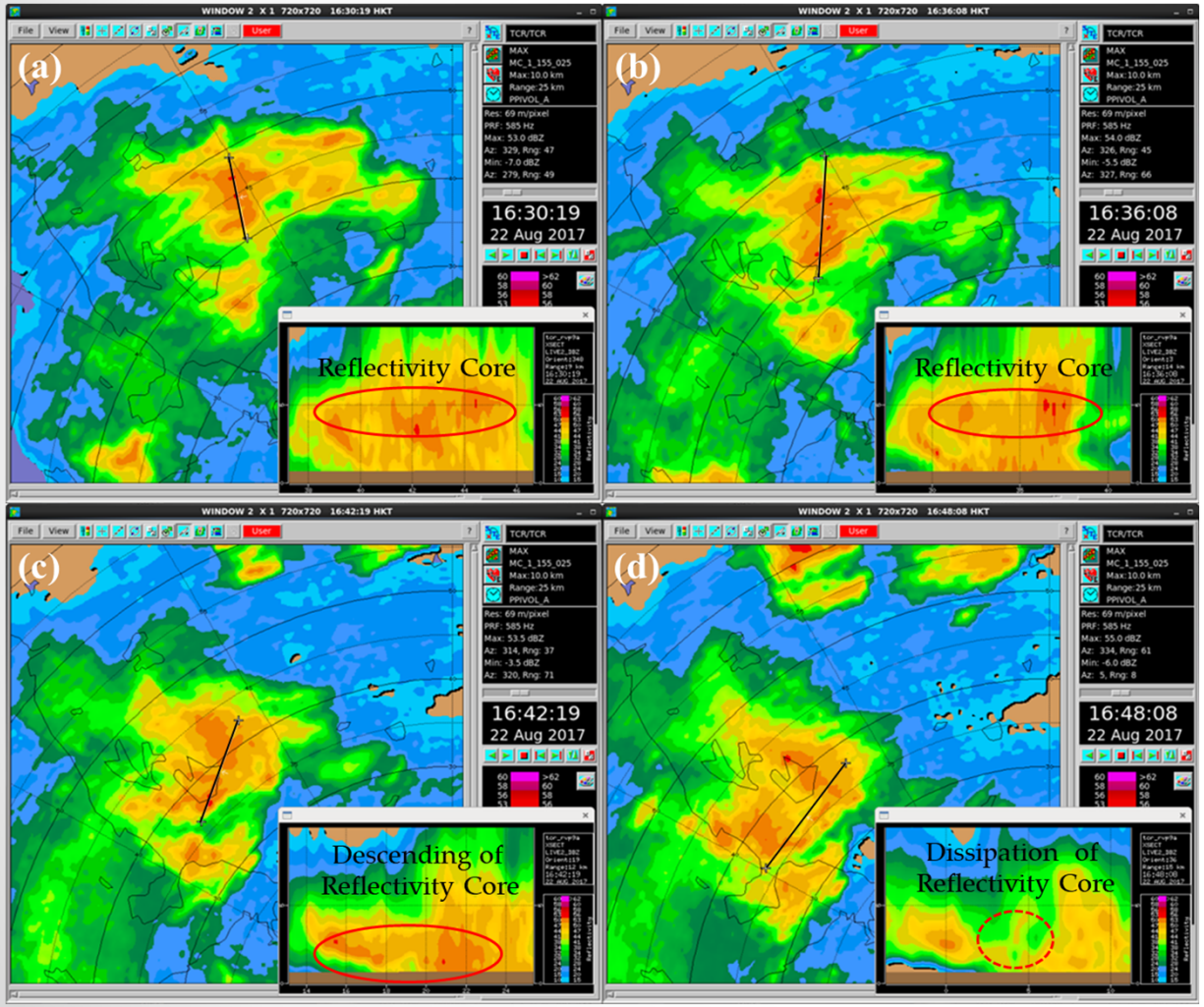


6-min radar imagery animation



1-min radar imagery animation

Enhanced observations II - Downburst

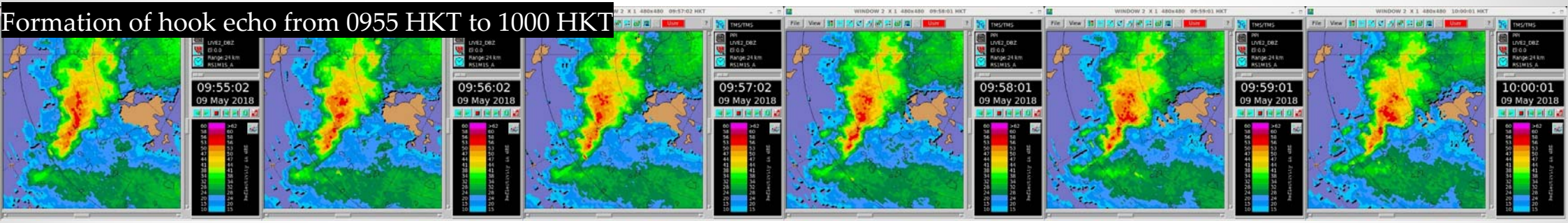


- Cross-section based on TCWR 6-minute volume scan data revealed descending of the reflectivity core.
- Another evidence of downburst process observed from the vertical direction.
- Combined use of rapid scan and volume scan could provide a wider perspective in observing the evolution and impact of severe weather.

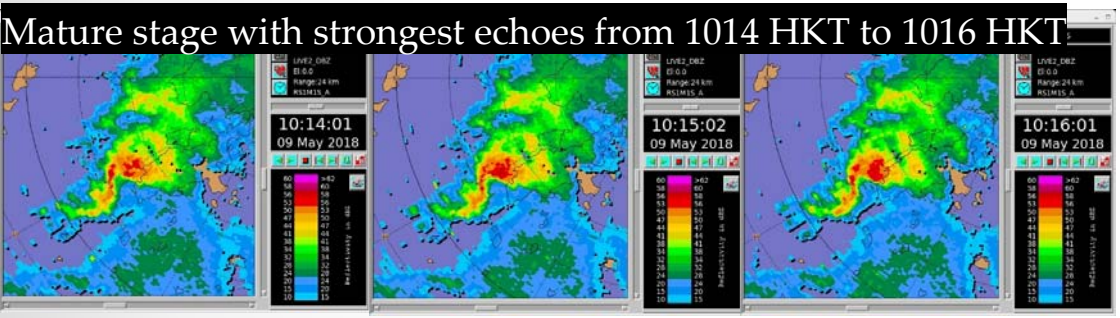
香港天文台
HONG KONG OBSERVATORY

Enhanced observations III – Hook echo

Formation of hook echo from 0955 HKT to 1000 HKT

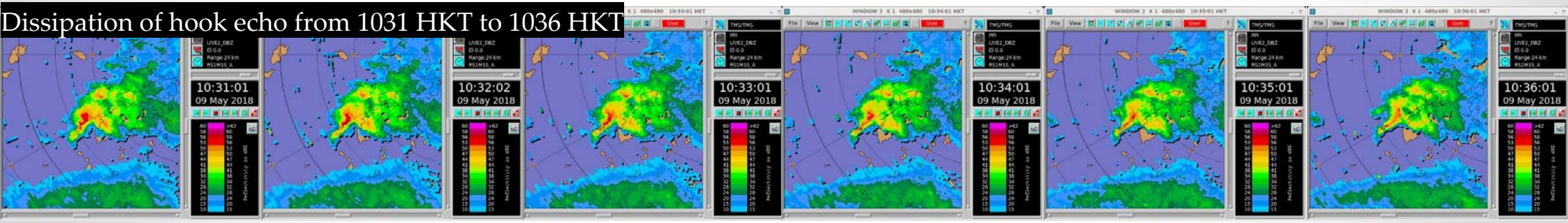


Mature stage with strongest echoes from 1014 HKT to 1016 HKT



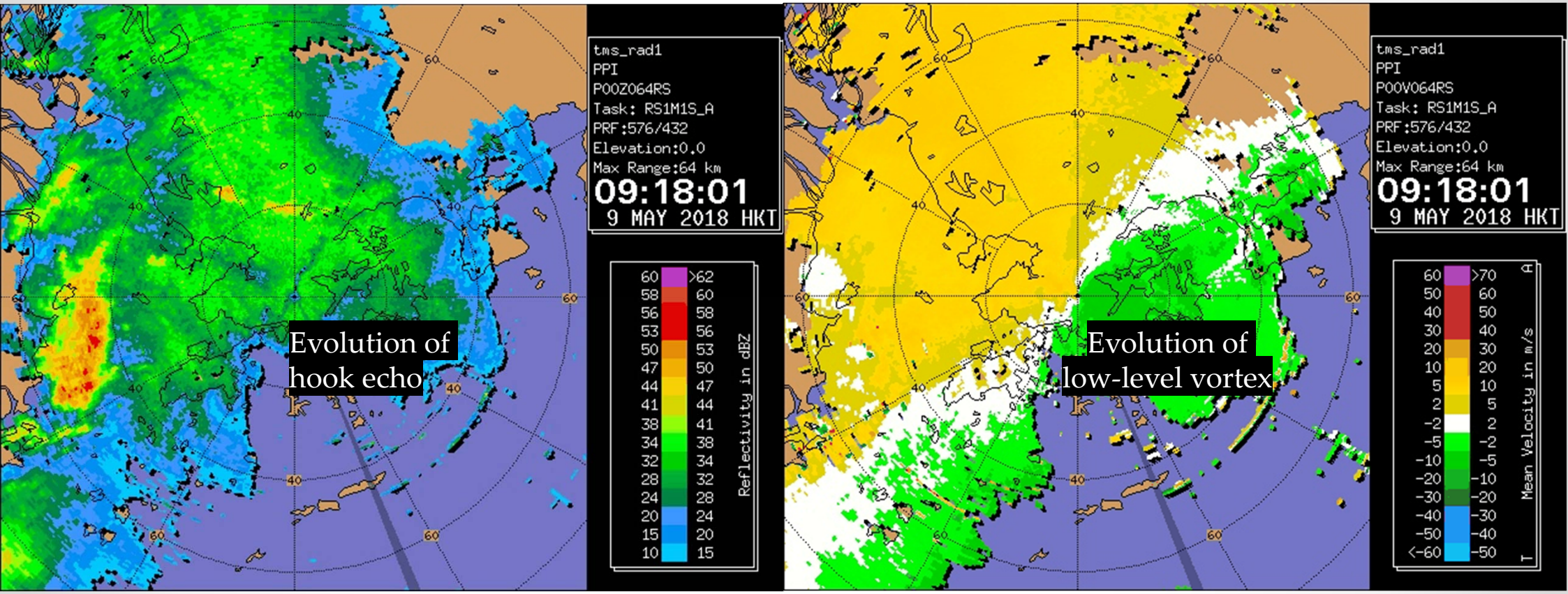
- Formation and dissipation processes lasted for around 6 minutes or less -> difficult to be observed using 6-min imageries
- The strongest echoes appeared outside T+0, T+6, T+12……

Dissipation of hook echo from 1031 HKT to 1036 HKT



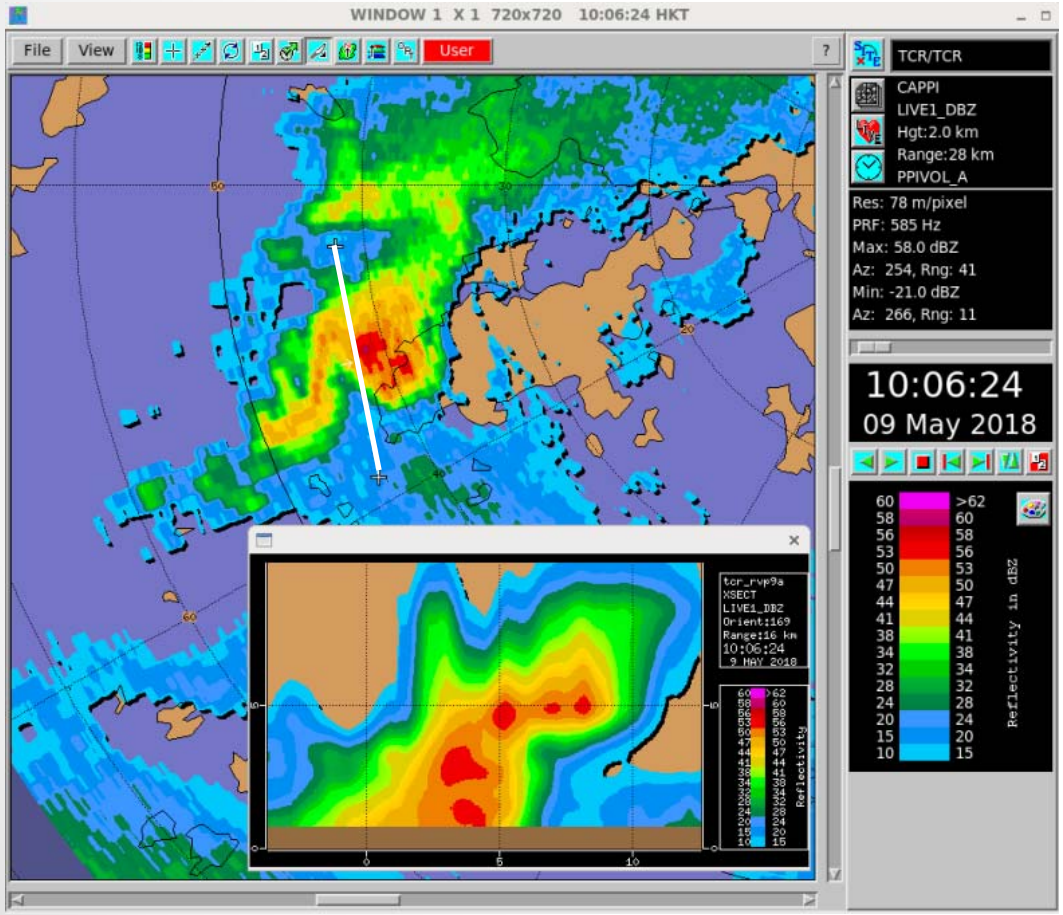
香港天文台
HONG KONG OBSERVATORY

Enhanced observations III – Hook echo



1-min radar imagery animation

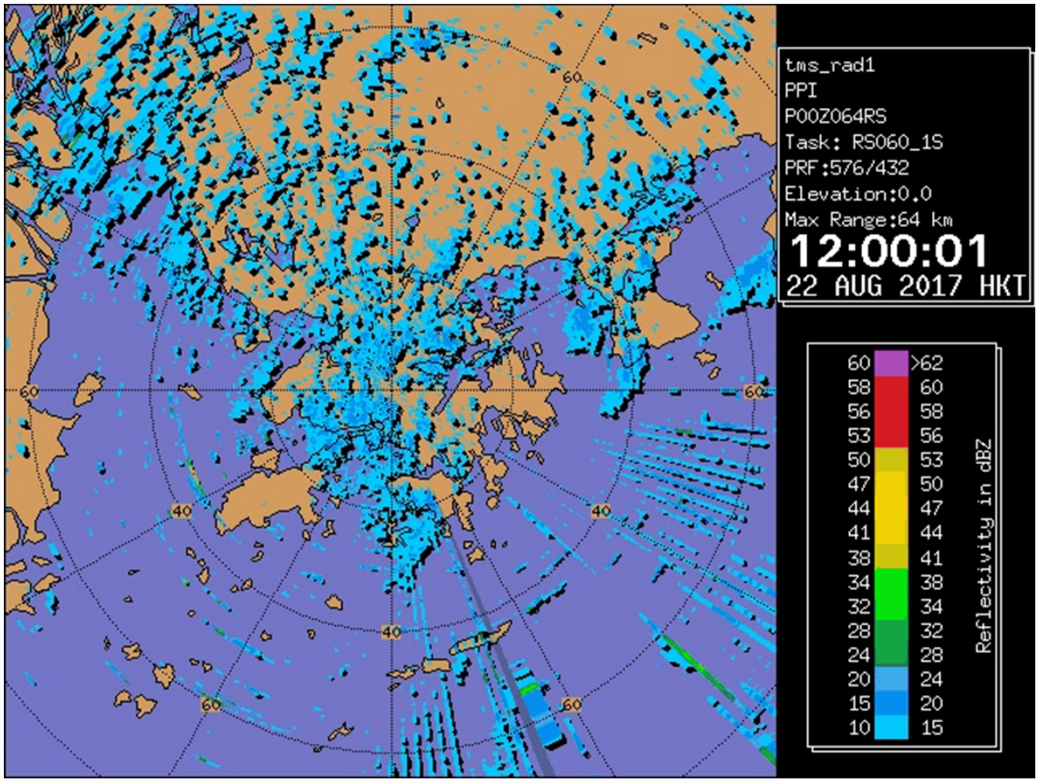
Enhanced observations III – Hook Echo

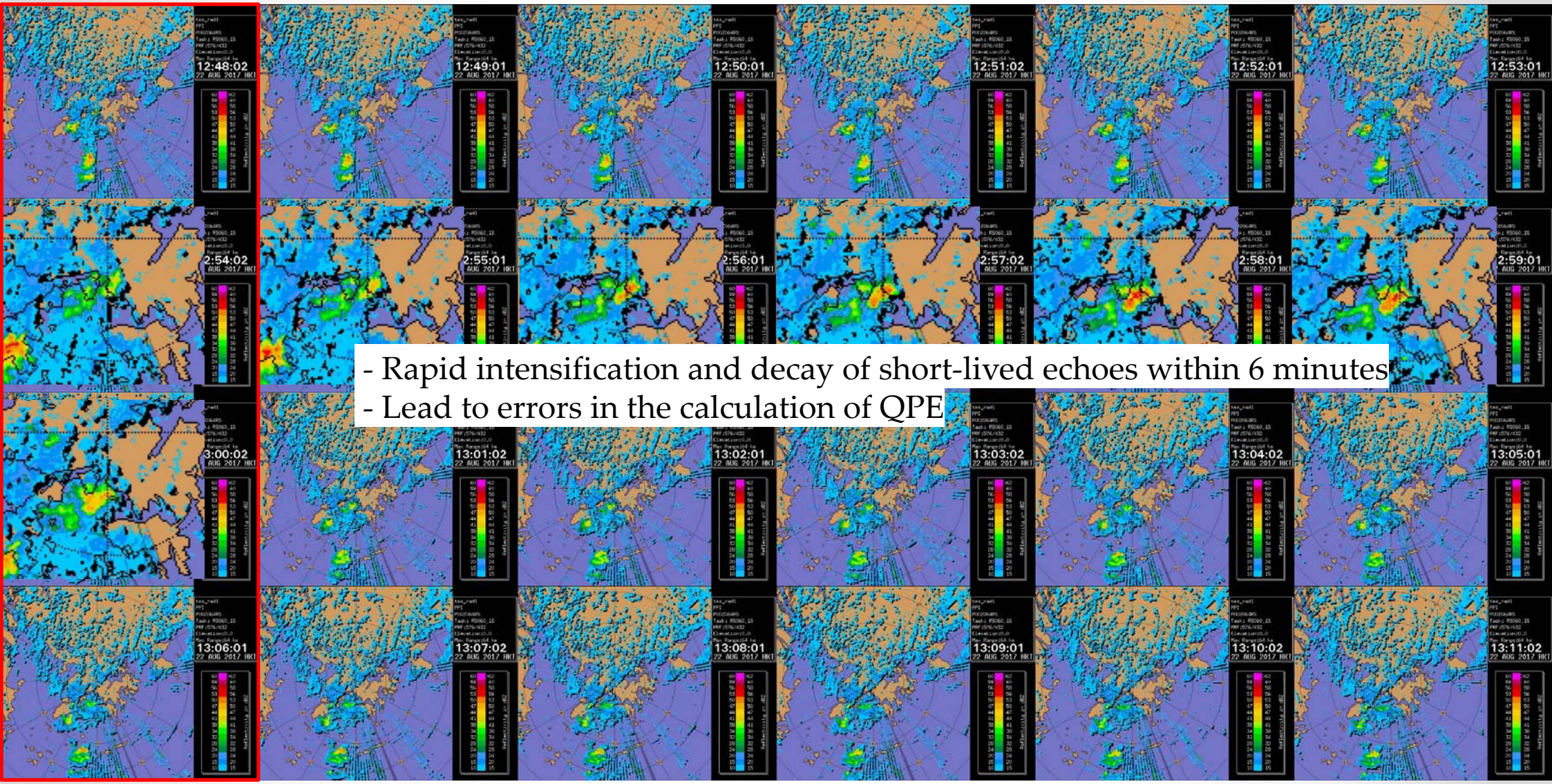


- Cross-section based on TCWR 6-minute volume scan data revealed overhang echo.
- Another evidence of hail possibility.
- Again illustrated the advantage of combined use of rapid scan and volume scan.

香港天文台
HONG KONG OBSERVATORY

Enhanced observations IV




12:48:02
12:49:01
12:50:01
12:51:02
12:52:01
12:53:01
2:54:02
2:55:01
2:56:01
2:57:02
2:58:01
2:59:01
3:00:02
13:01:02
13:02:01
13:03:02
13:04:02
13:05:01
13:06:01
13:07:02
13:08:01
13:09:01
13:10:02
13:11:02
- Rapid intensification and decay of short-lived echoes within 6 minutes
- Lead to errors in the calculation of QPE

香港天文台
HONG KONG OBSERVATORY

Q&A