Blending of Multi-Sensing Nowcasting System and NWP Output to Improve Aviation Significant Convection Forecast

WSN16, 25-29 July, HK

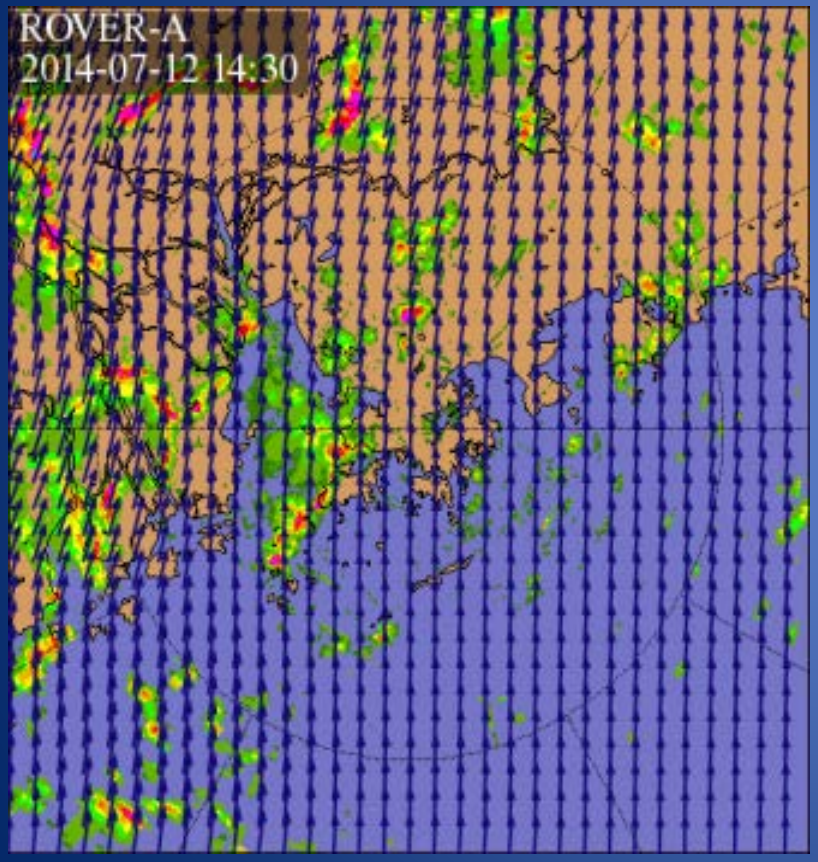
P CHEUNG/ Hong Kong Observatory

Aviation Thunderstorm Nowcasting System (ATNS) – Tailored for Aviation

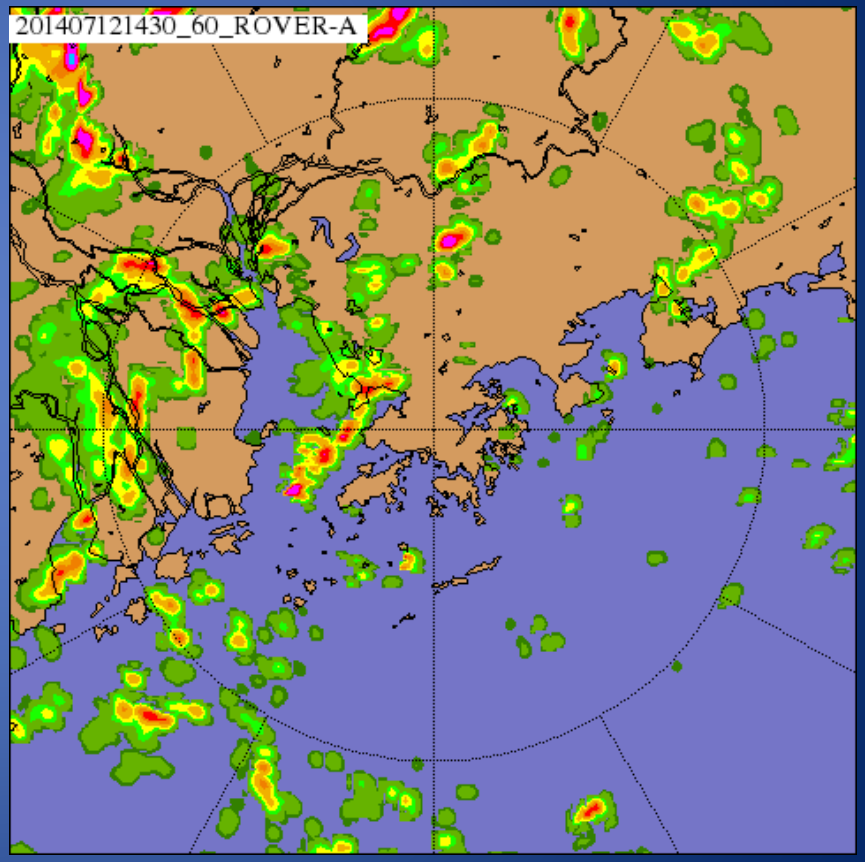
Actual

Extrapolated reflectivity after 60 minutes

SWIRLS – HKO's nowcasting system



Actual overlaid with motion field

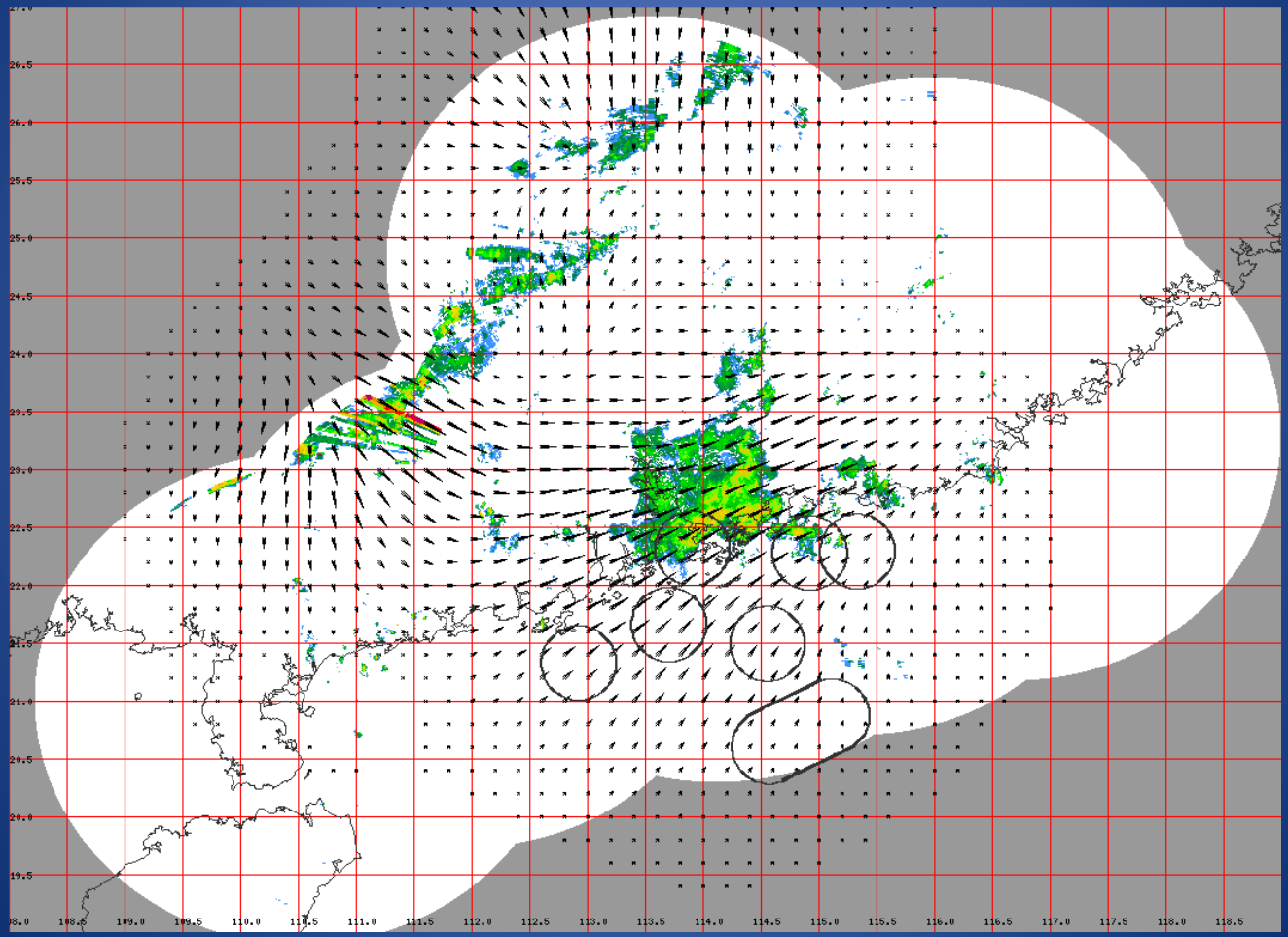


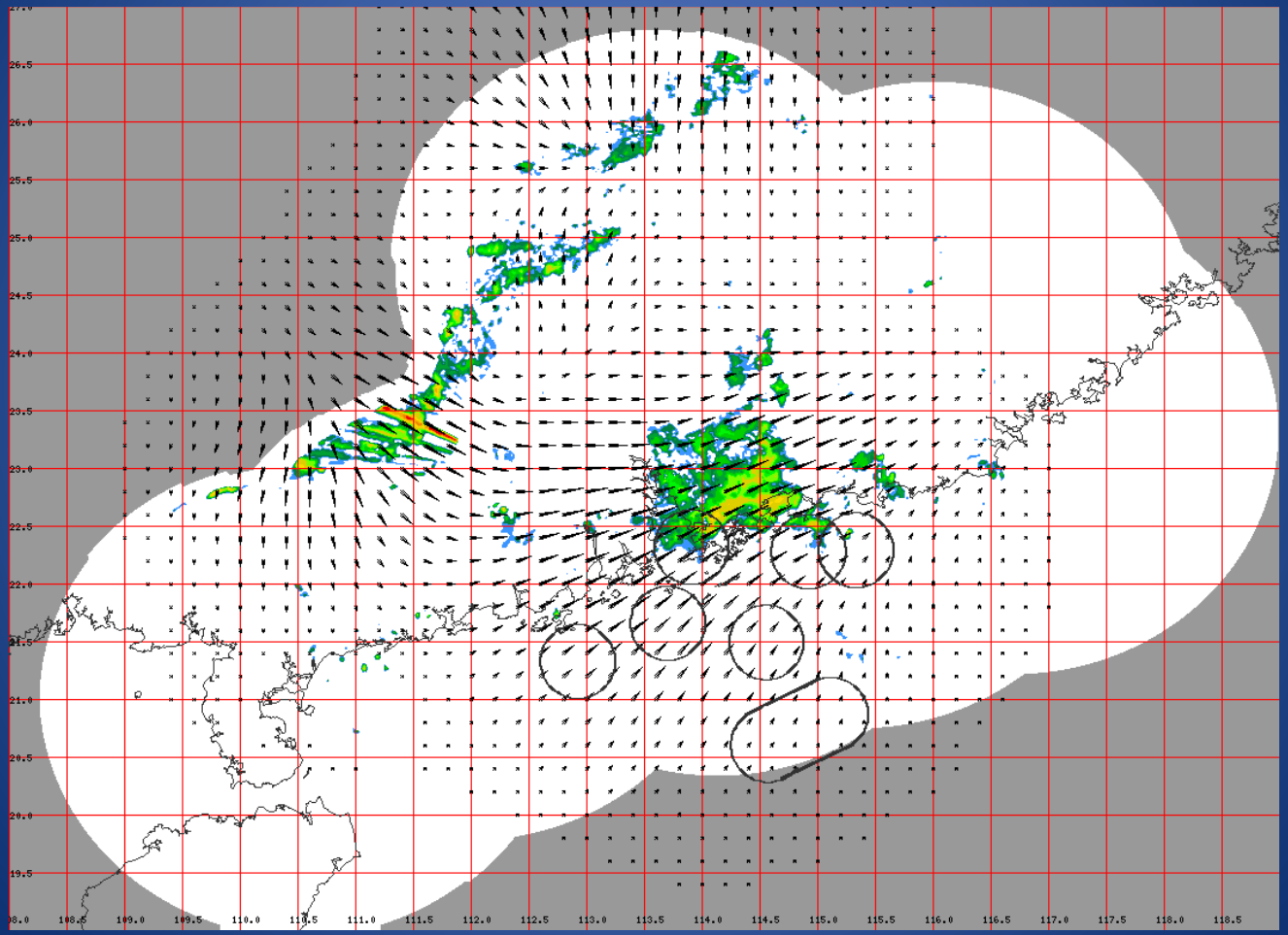
Extrapolated rainfall after 60 minutes

Limitations in extended nowcasting

1. Out of radar coverage
   - Mosiac from multiple radars

Case of 11 May 2014

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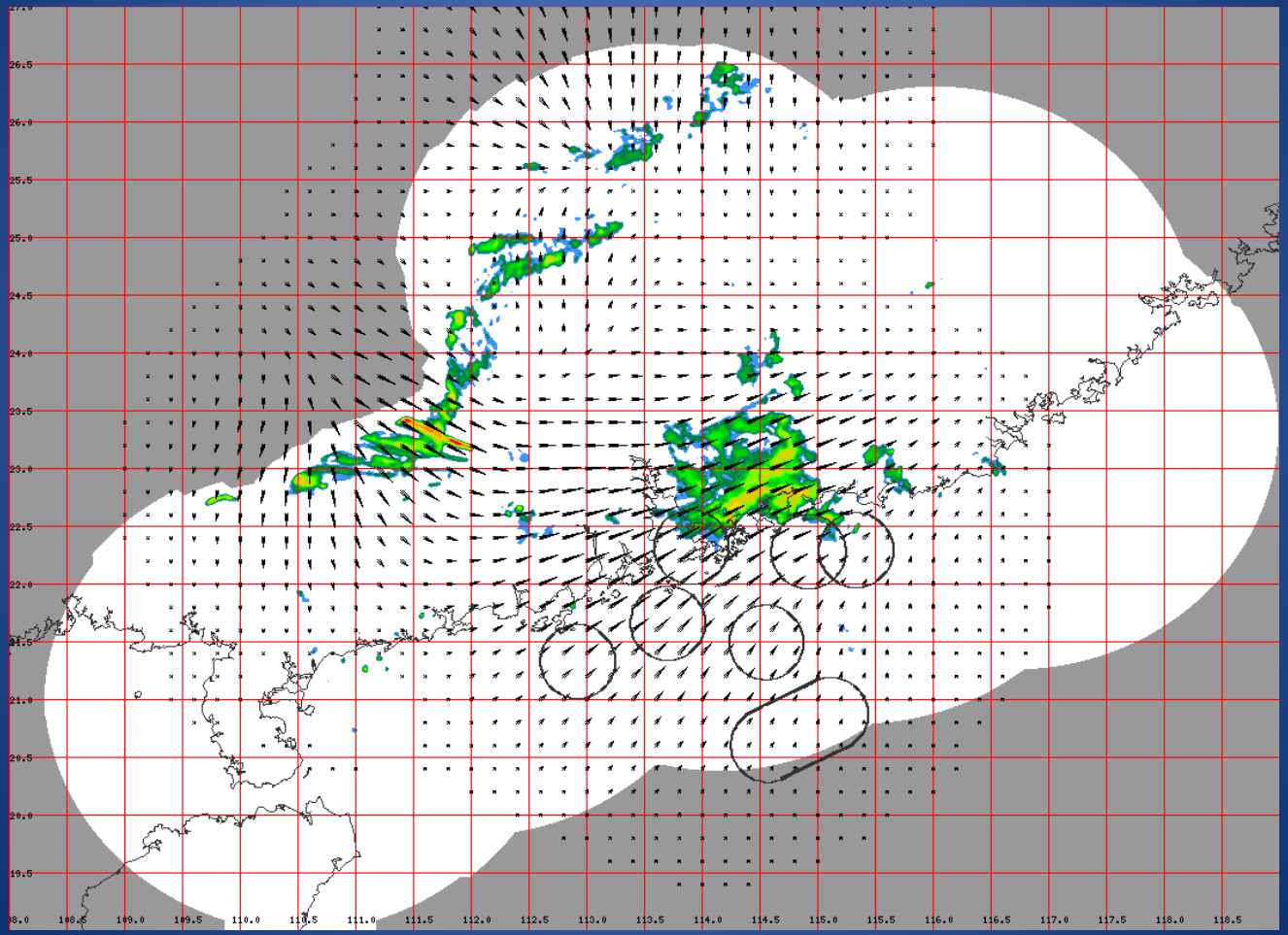
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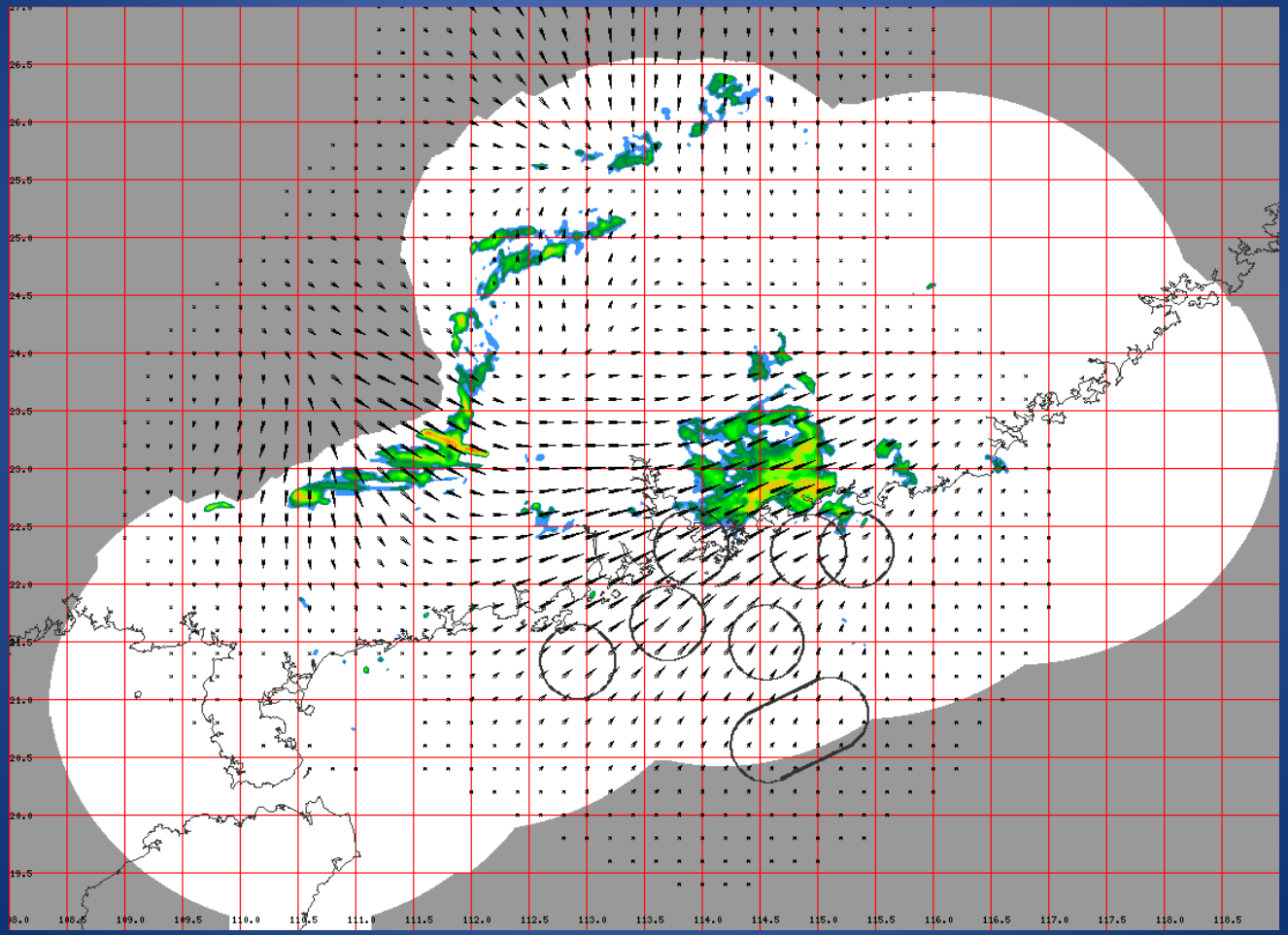
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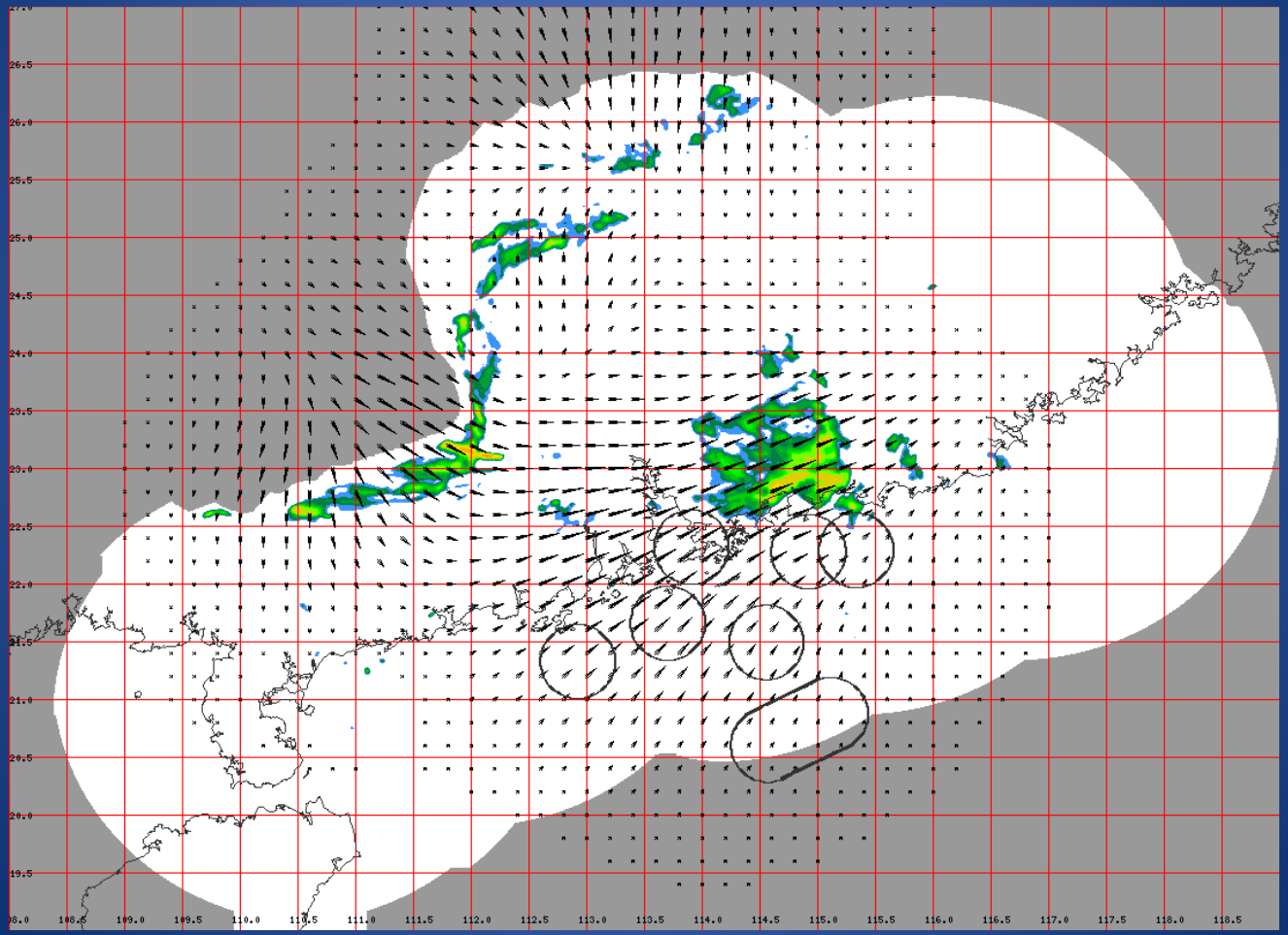
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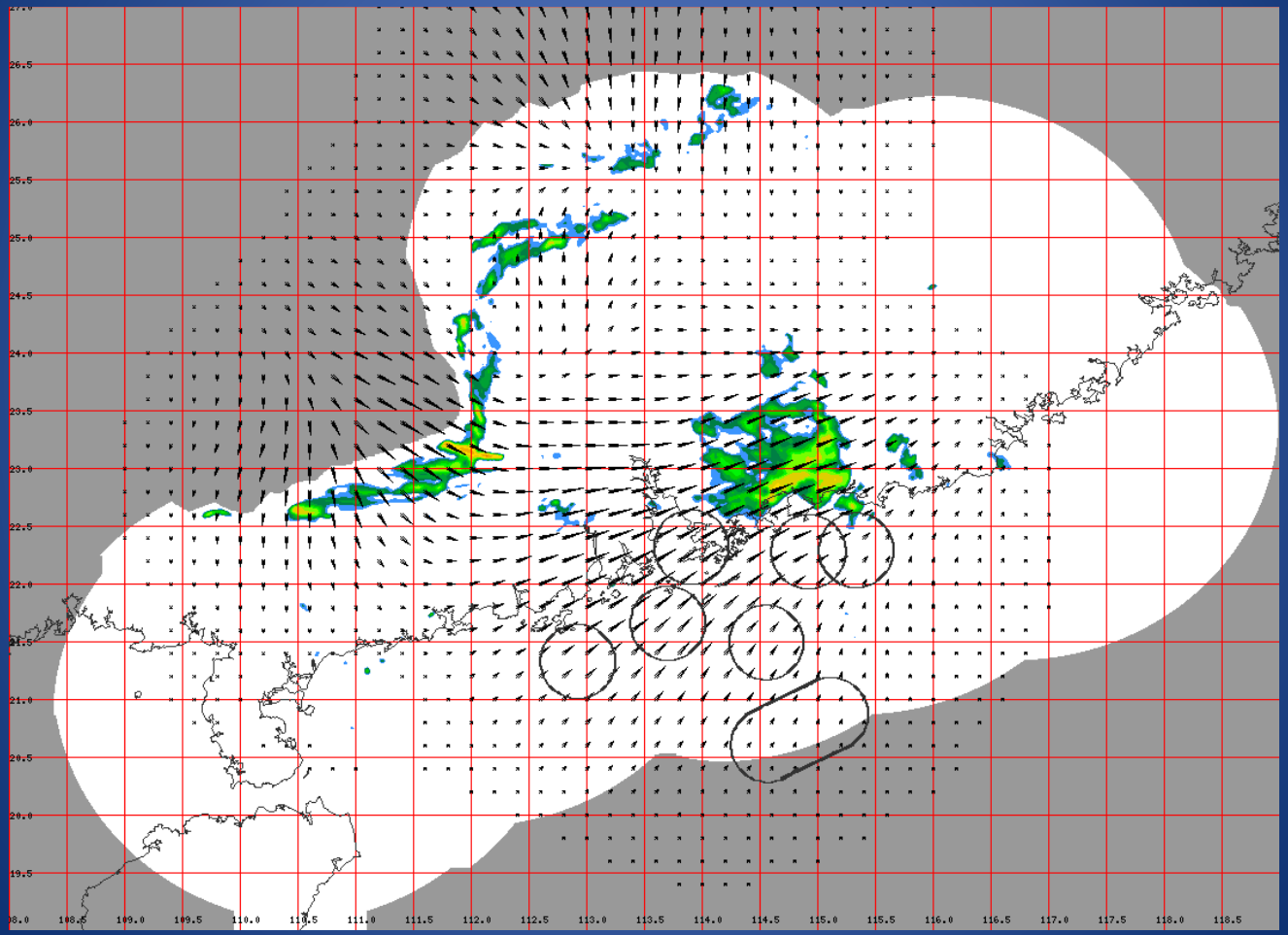
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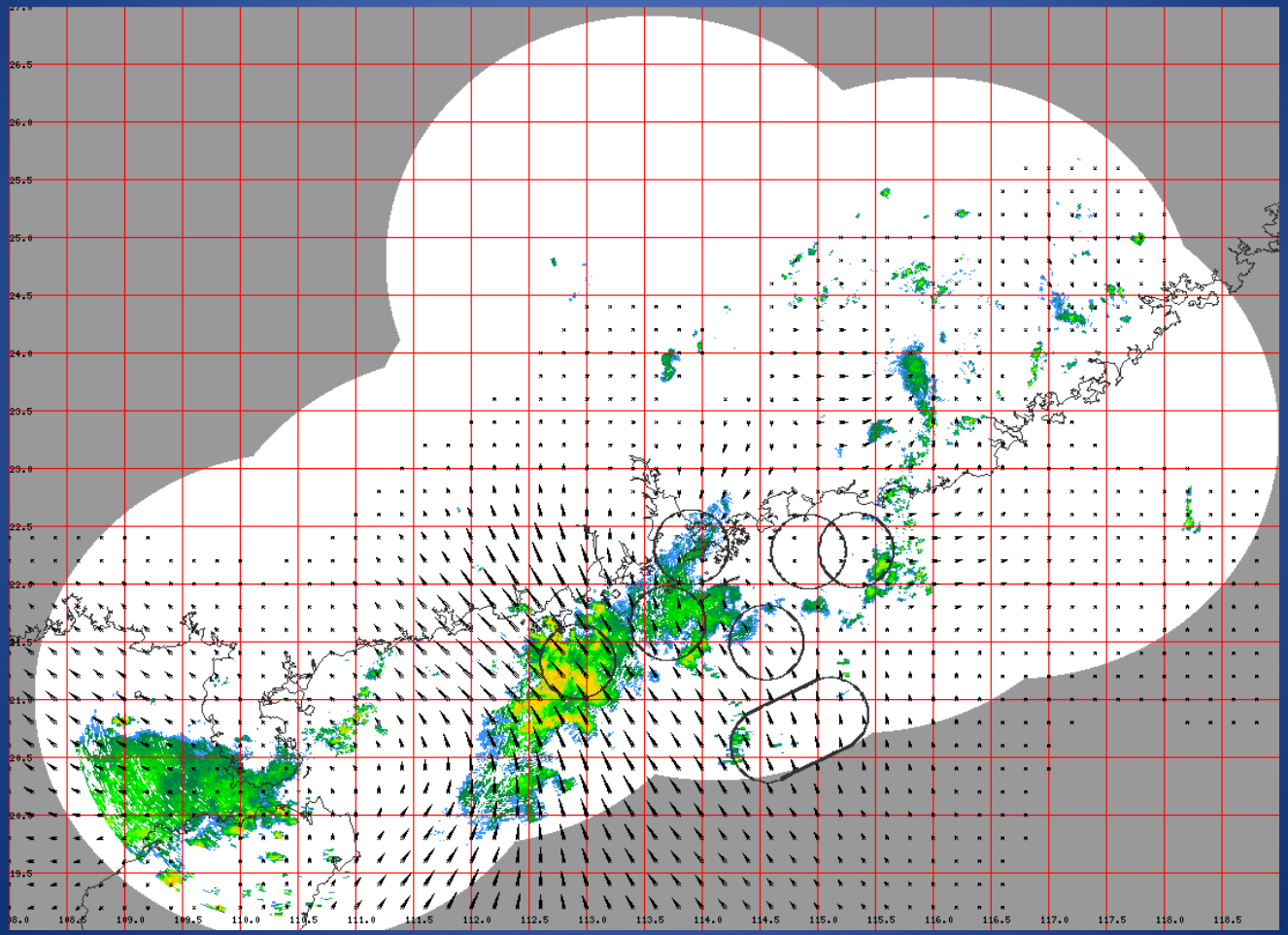
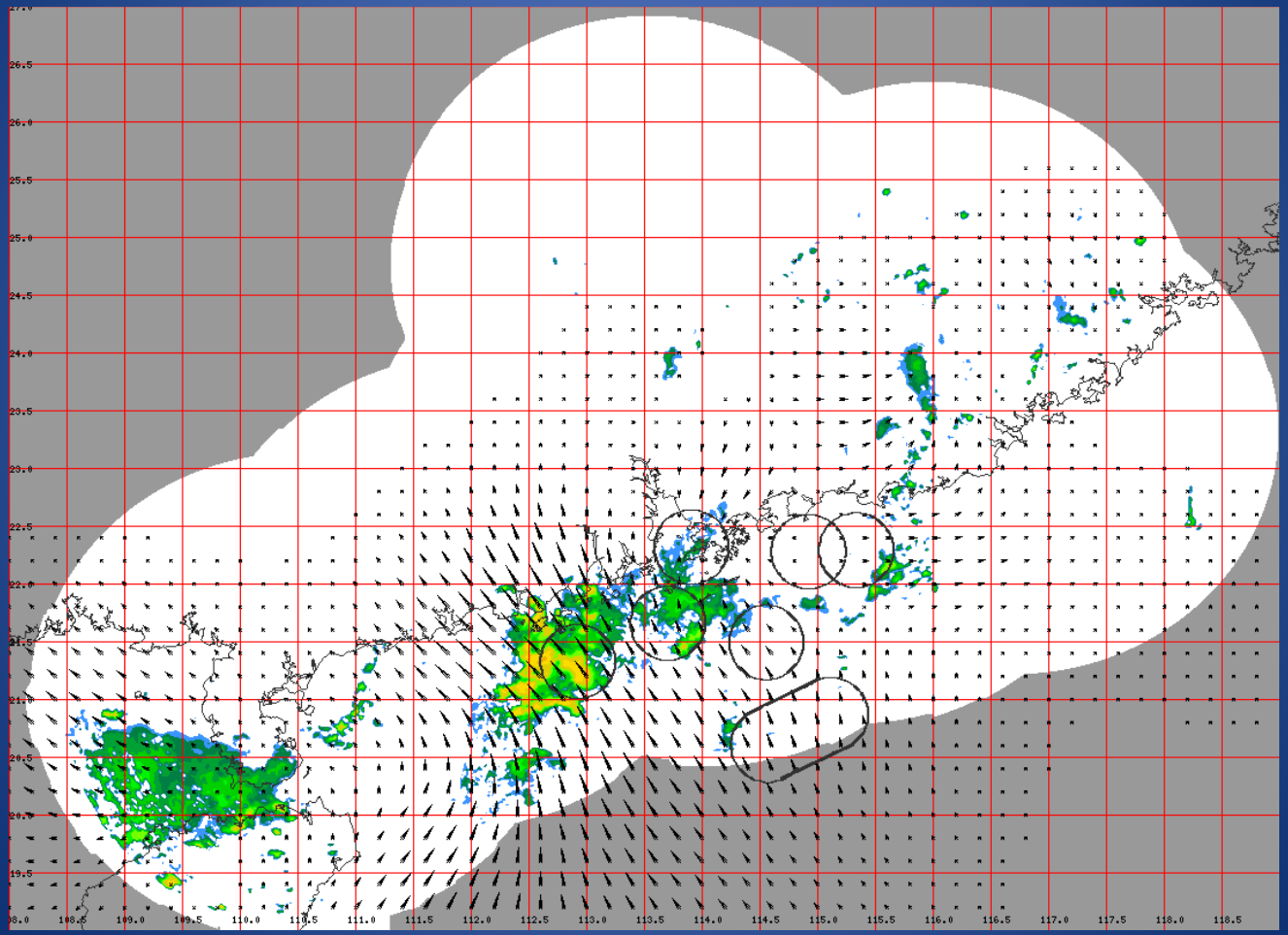
Another case of 22 Jun 2014

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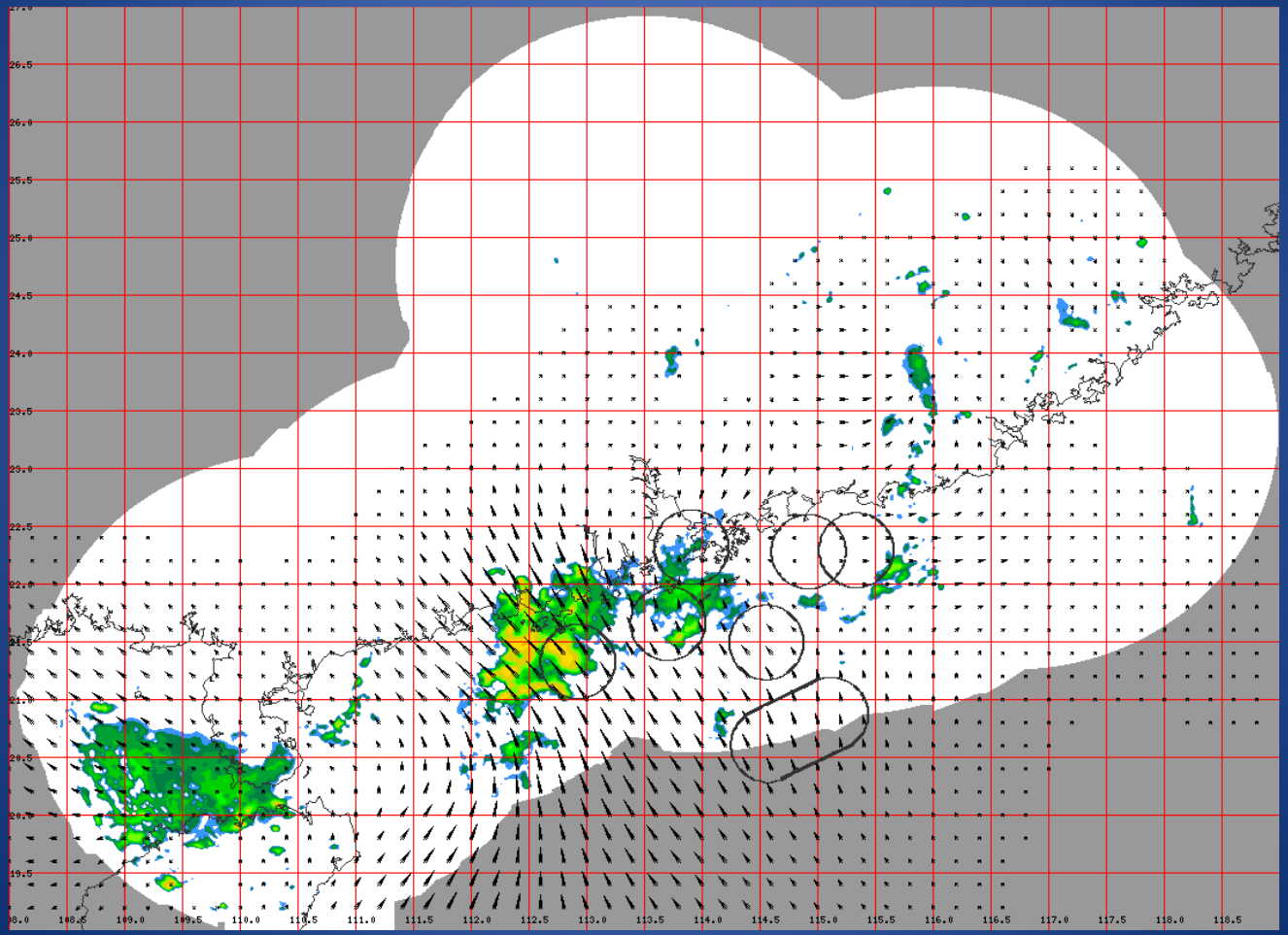
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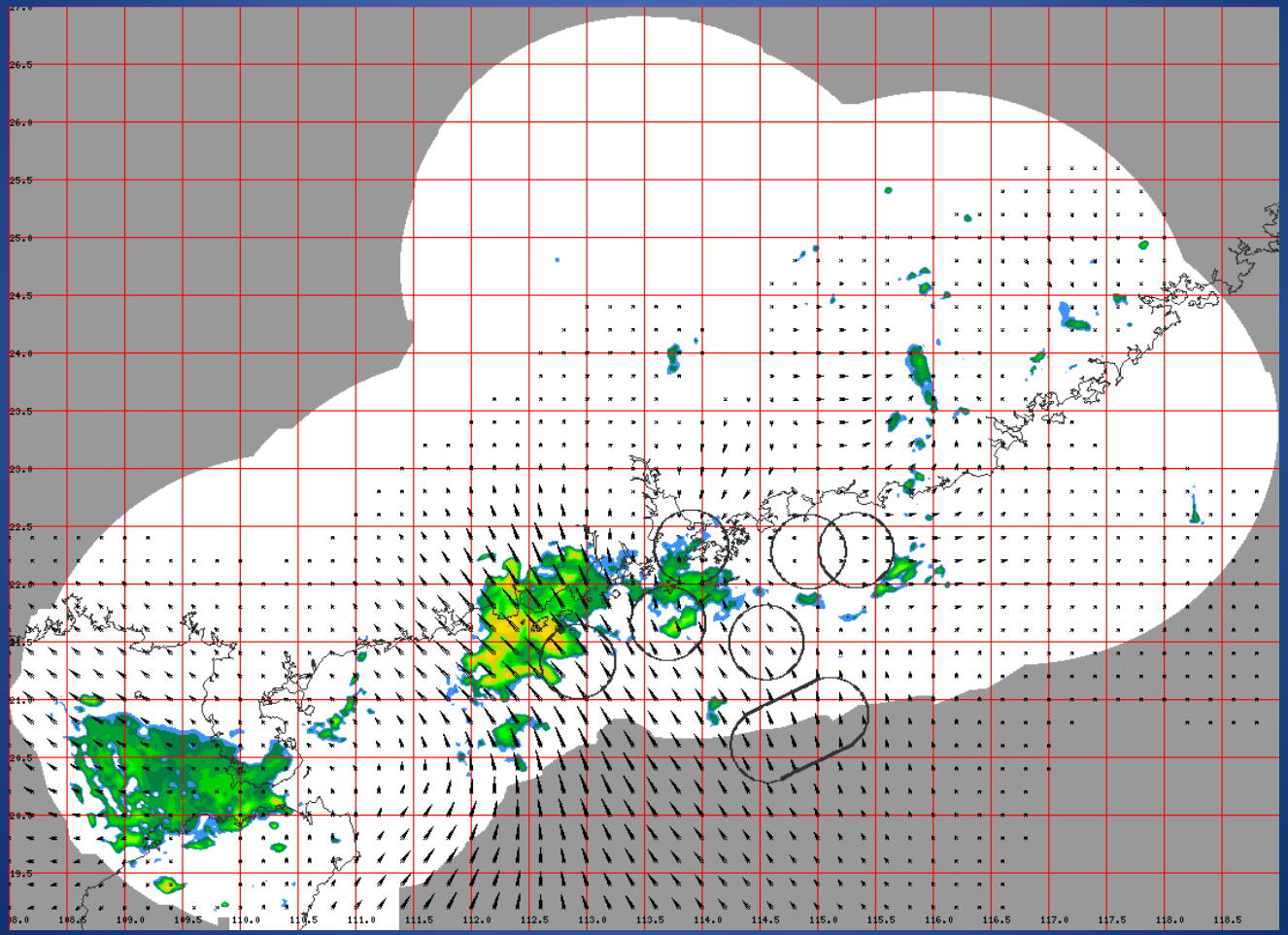
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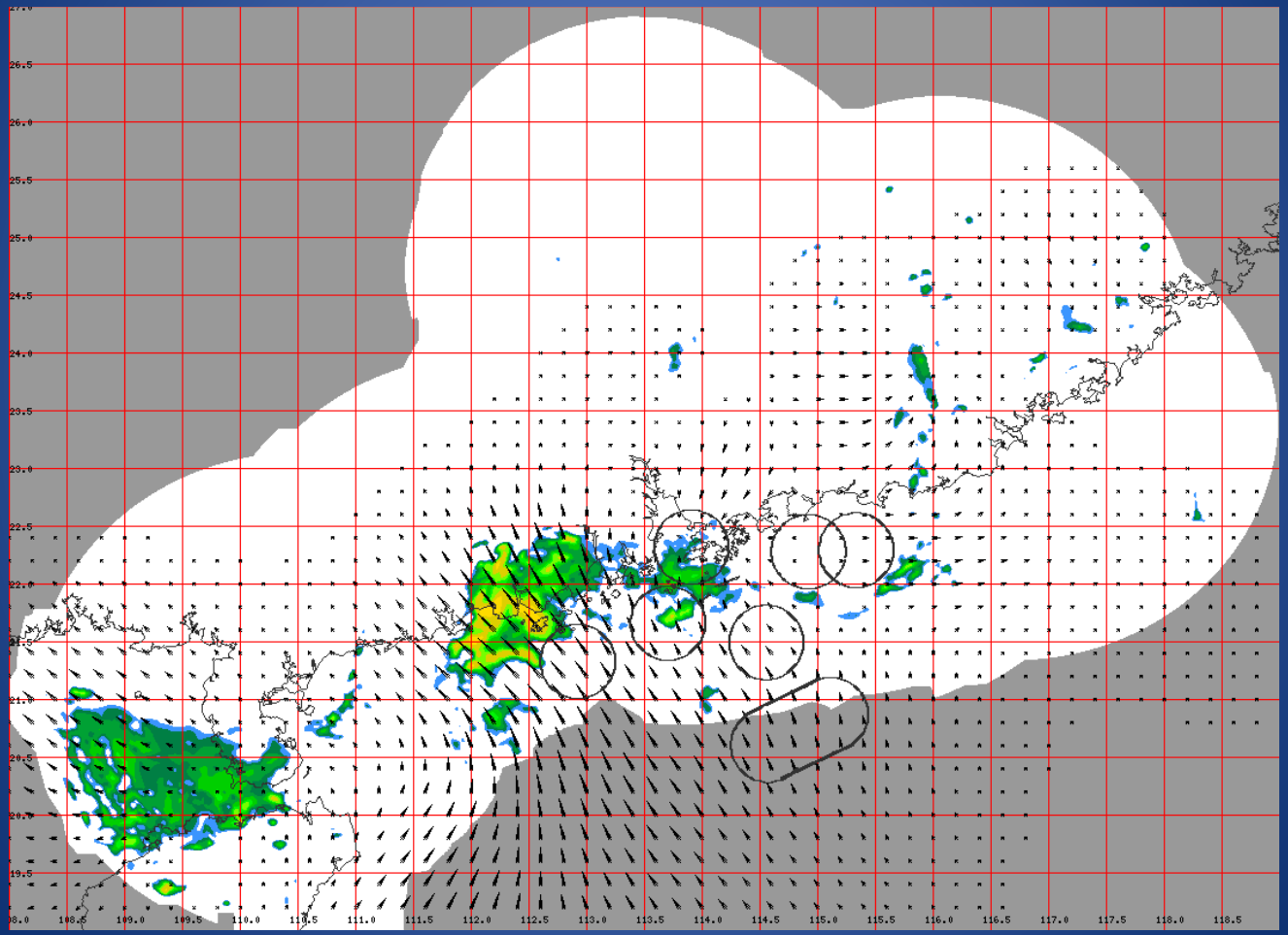
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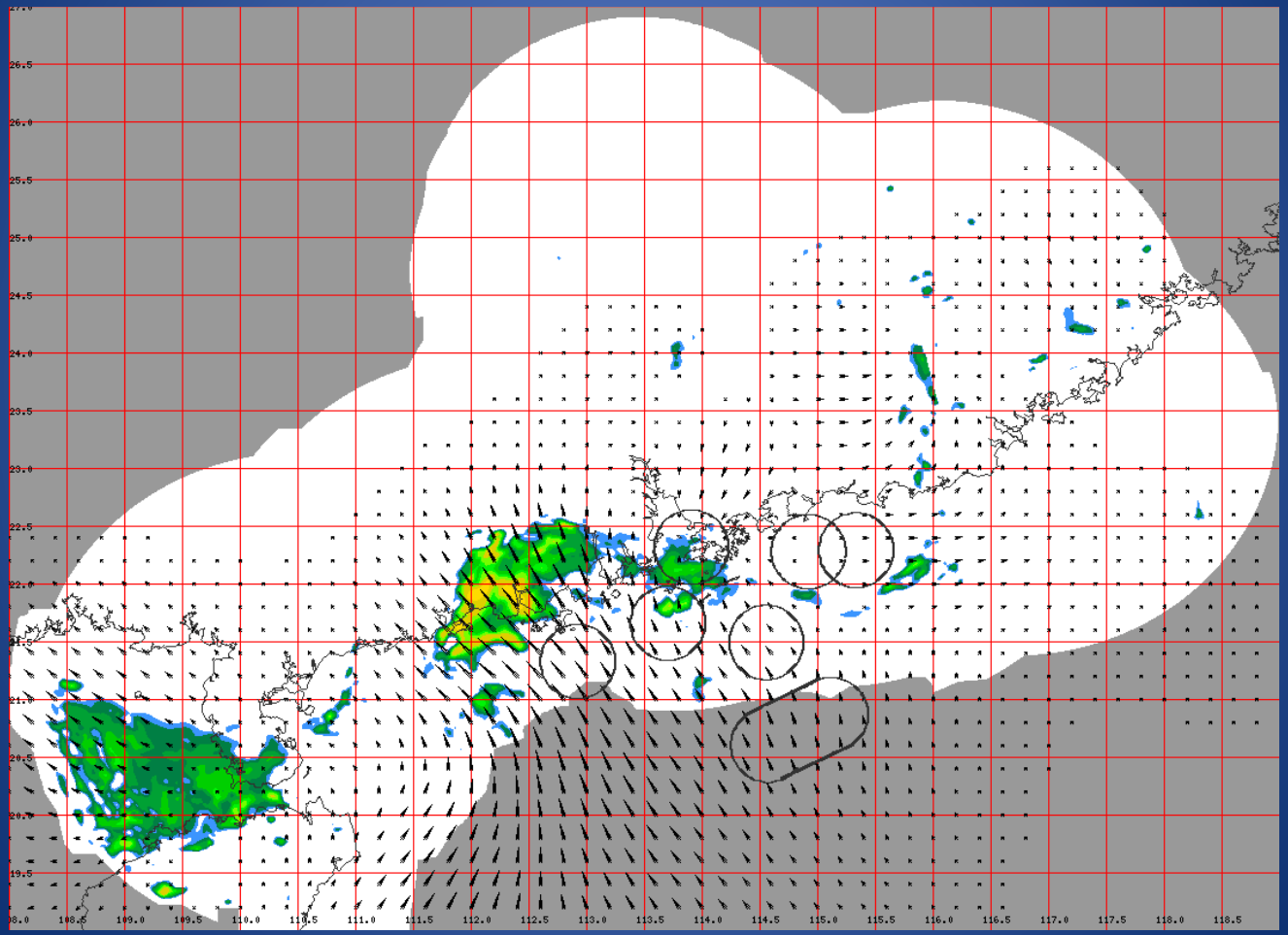
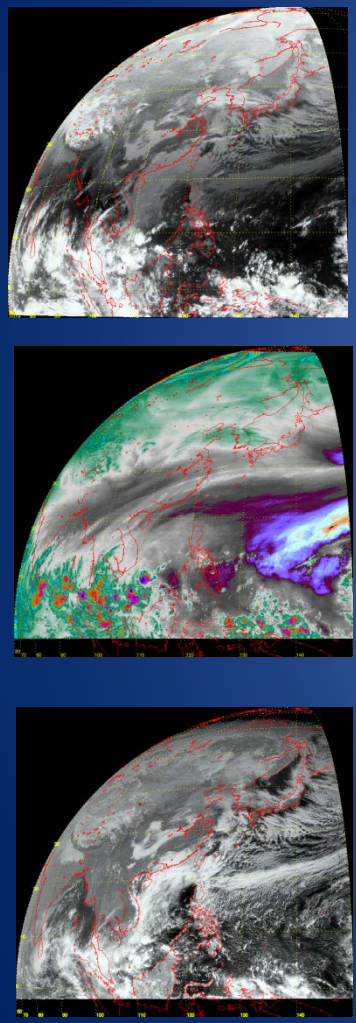
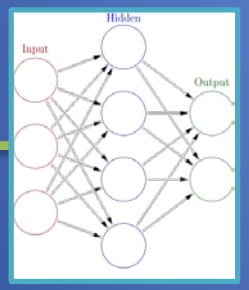


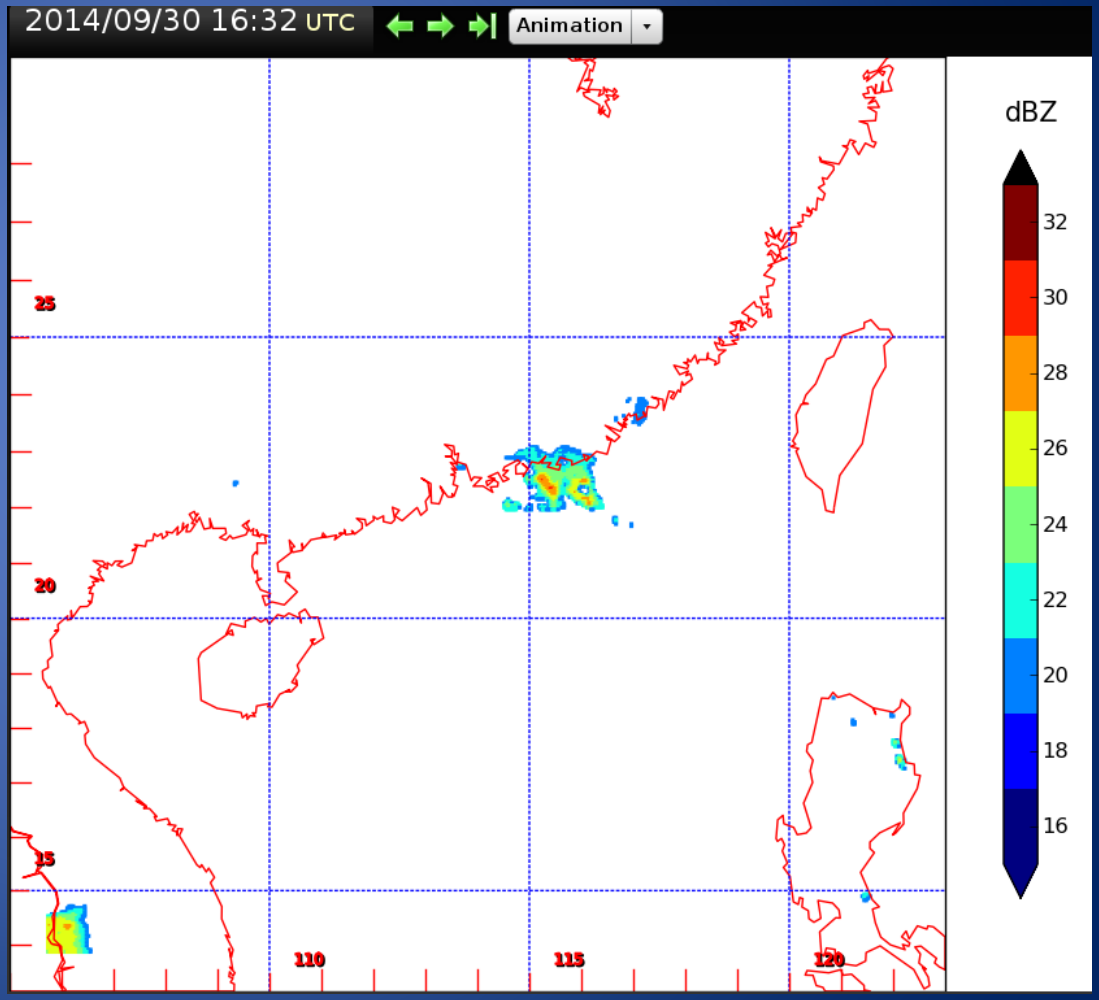
Limitations in extended nowcasting

1. Out of radar coverage
   - Radar mosiac, still no coverage off shore
   - Multi-source convection observation

ANN algorithm to convert satellite data into radar reflectivity

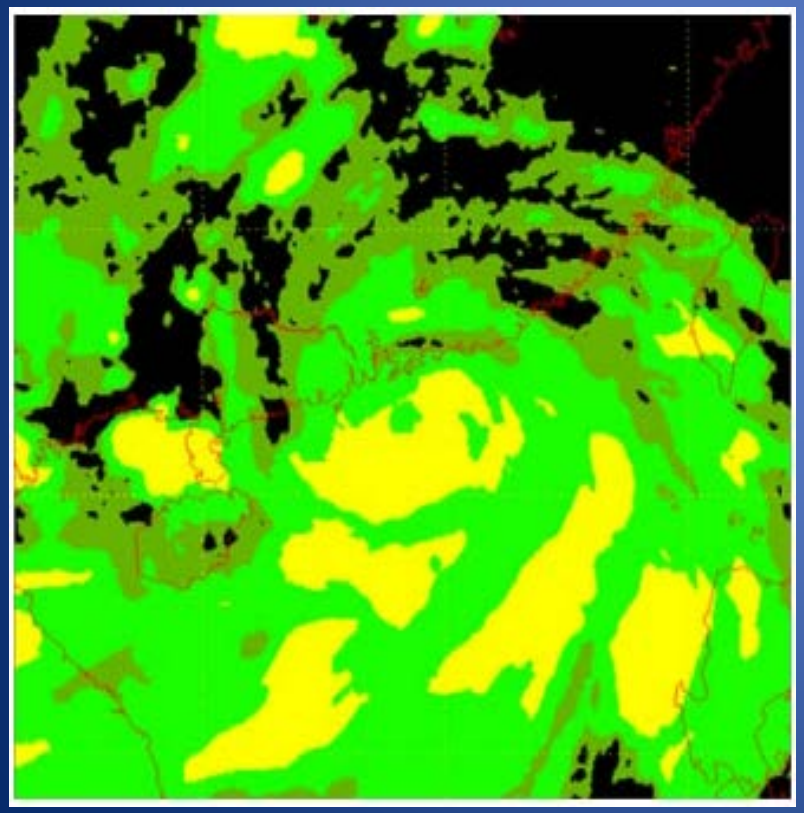




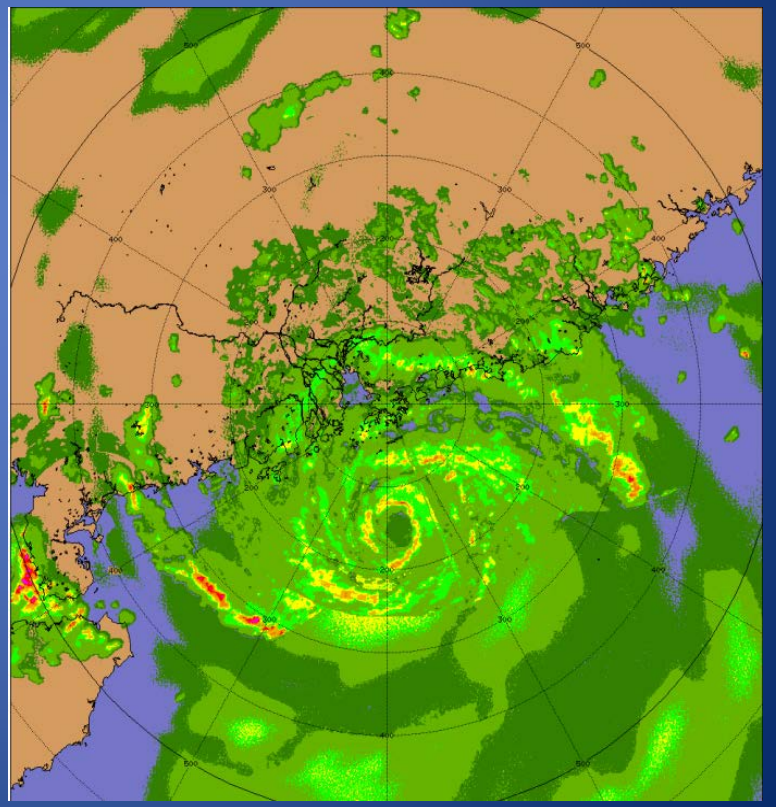


Radar + Satellite nowcasting

Purely satellite-based reflectivity estimate by machine learning

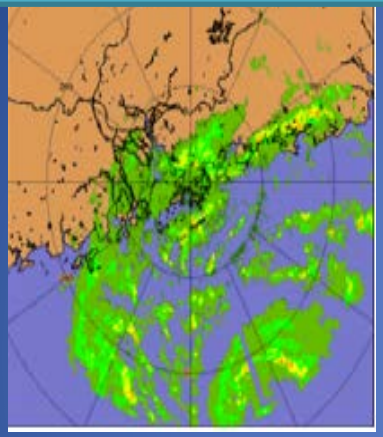


Satellite reflectivity merged with local radar data

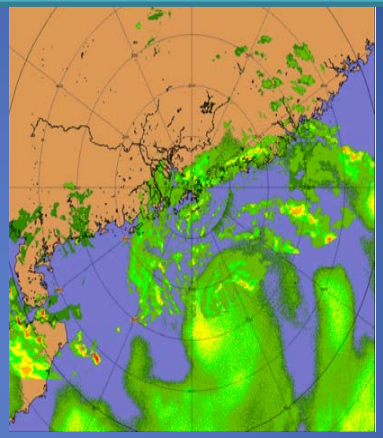


Radar+Satellite nowcasting benefit

T0 only radar

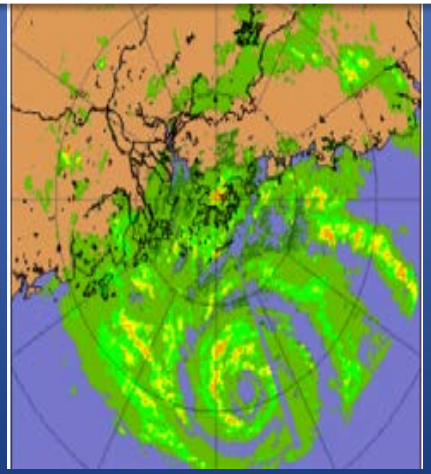


T0 Radar + satellite

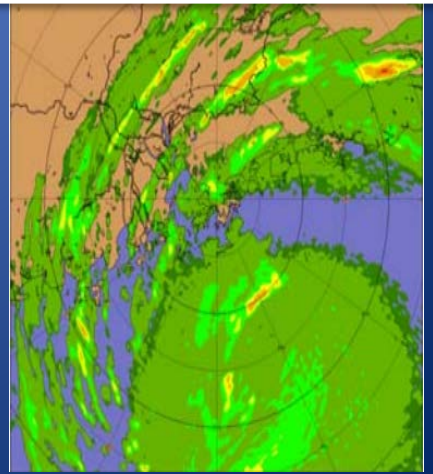


+6hr radar nowcast

+6hr actual



+6hr radar+satellite nowcast

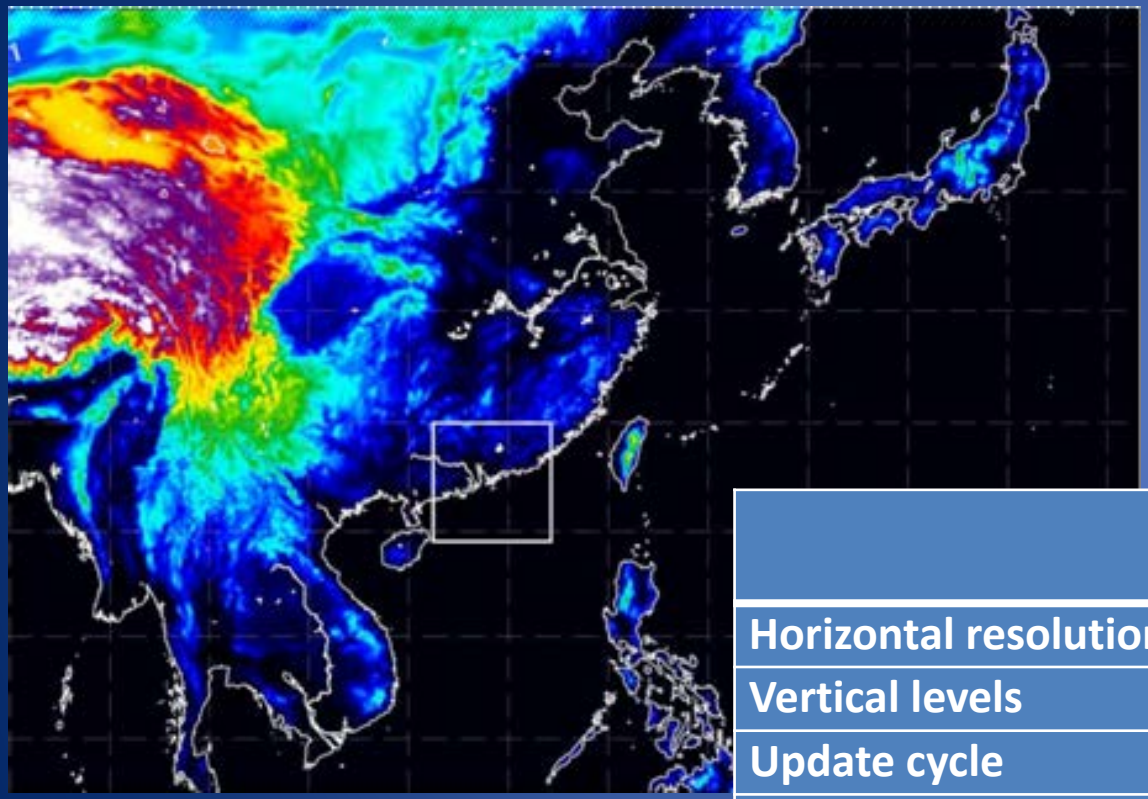


Limitations in extended nowcasting

1. Out of radar coverage
   - Radar mosiac
   - Multi-source convection observation

2. No initiation/growth/decay/development
   - Merge with NWP

HKO's NWP – Meso NHM and RAPIDS NHM



	Meso-NHM	RAPIDS-NHM
Horizontal resolution	10km	2km
Vertical levels	50	60
Update cycle	3hr	1hr
Forecast range	72hr	15hr
Boundary condition	ECMWF	Meso-NHM
Data assimilation	3DVAR	3DVAR

Merging/Blending/Mixing/Crossover to get advantage of both sides (?)

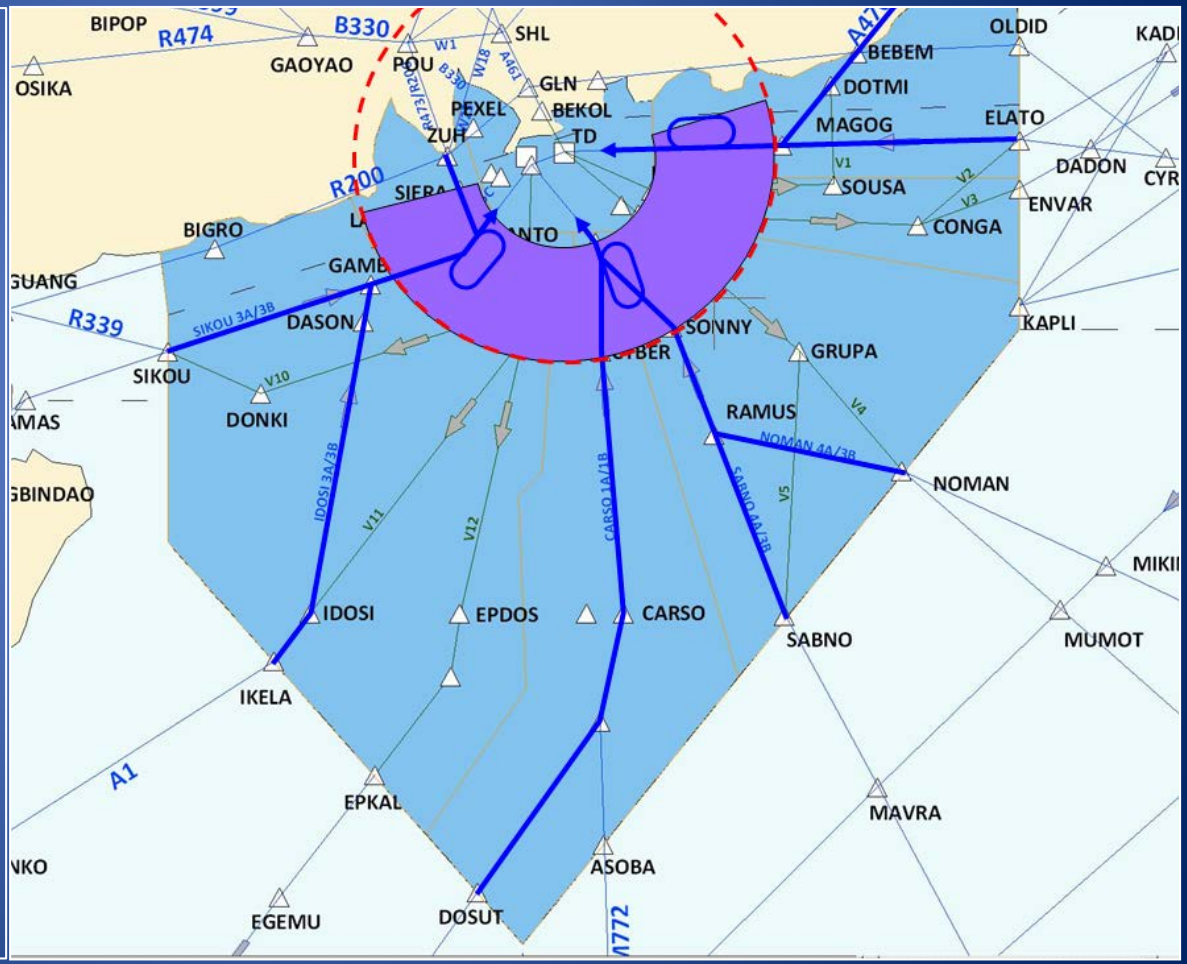
1. Choose a suitable horizontal scale
2. Extract the right information from Nowcast system/NWP model
3. Select the weighting

Merging/Blending/Mixing/Crossover to get advantage of both sides (?)

1. **Choose a suitable horizontal scale**
   - **model forecast position error**
   - **uncertainty of motion vectors**

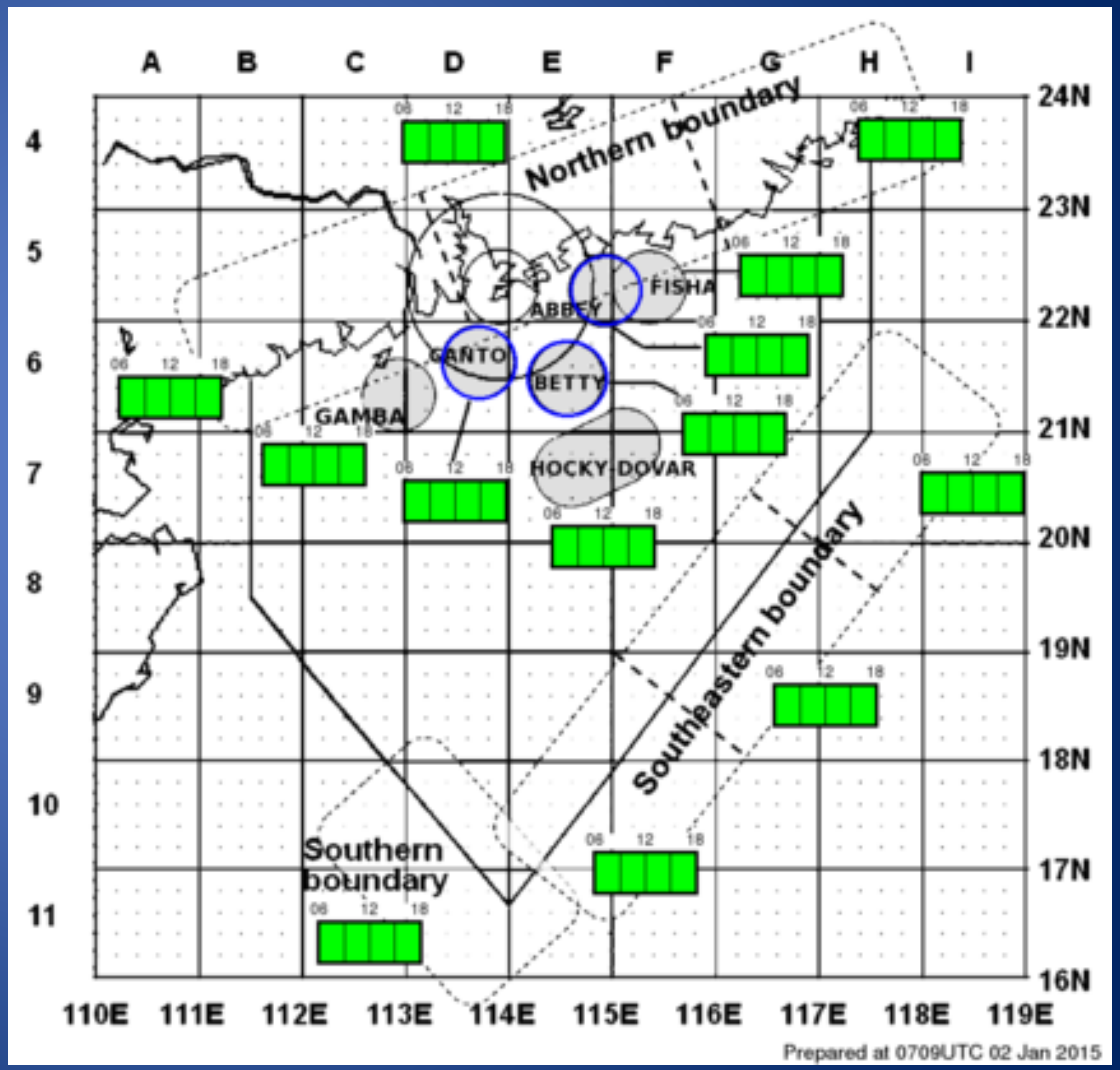
What scale suits the user?

- The blue shade is the HKFIR
- 3 major arrival feeds
- Some areas are more important

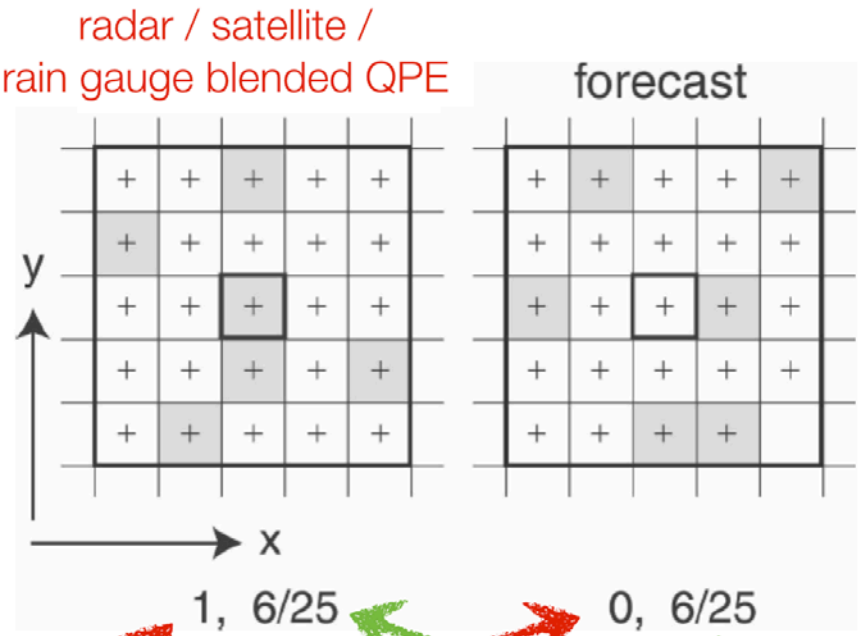


What scale to use?

- Grey areas are the main holding patterns
- Blue circles, the 3 major feeds
- Typical size is **20NM** in radius



Fraction Skill Score



Fraction Skill Score (FSS)

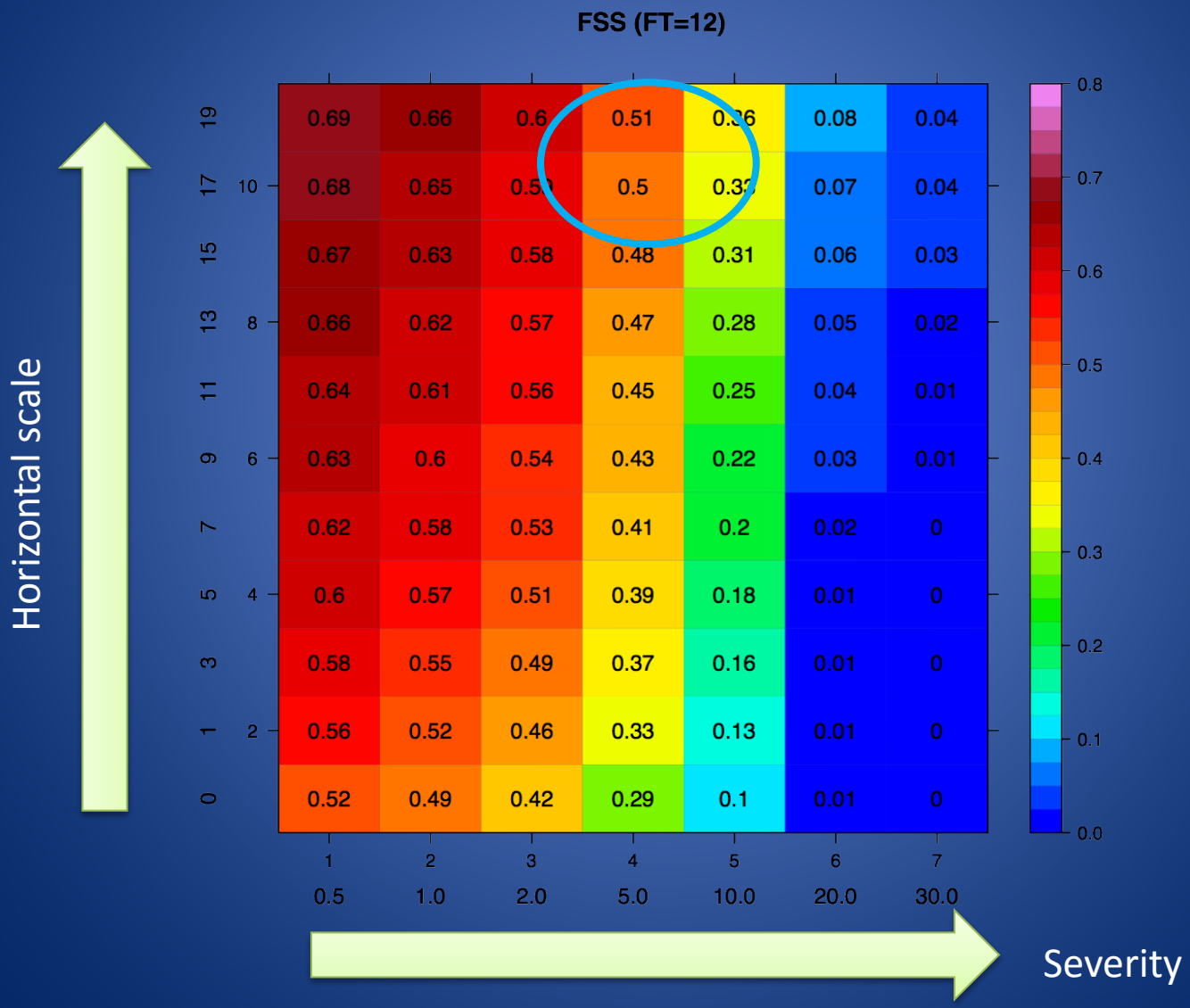
$$FSS = 1 - \frac{FBS}{\frac{1}{N}\left[\sum_N P_{fcst}^2 + \sum_N P_{obs}^2\right]}$$

$$FBS = \frac{1}{N}\sum_N \left(P_{fcst} - P_{obs}\right)^2$$

grid-by-grid verification

a fraction score indicating forecast has good match at a spatial uncertainty of +/- 2 grid sizes

knowing the NWP capability?

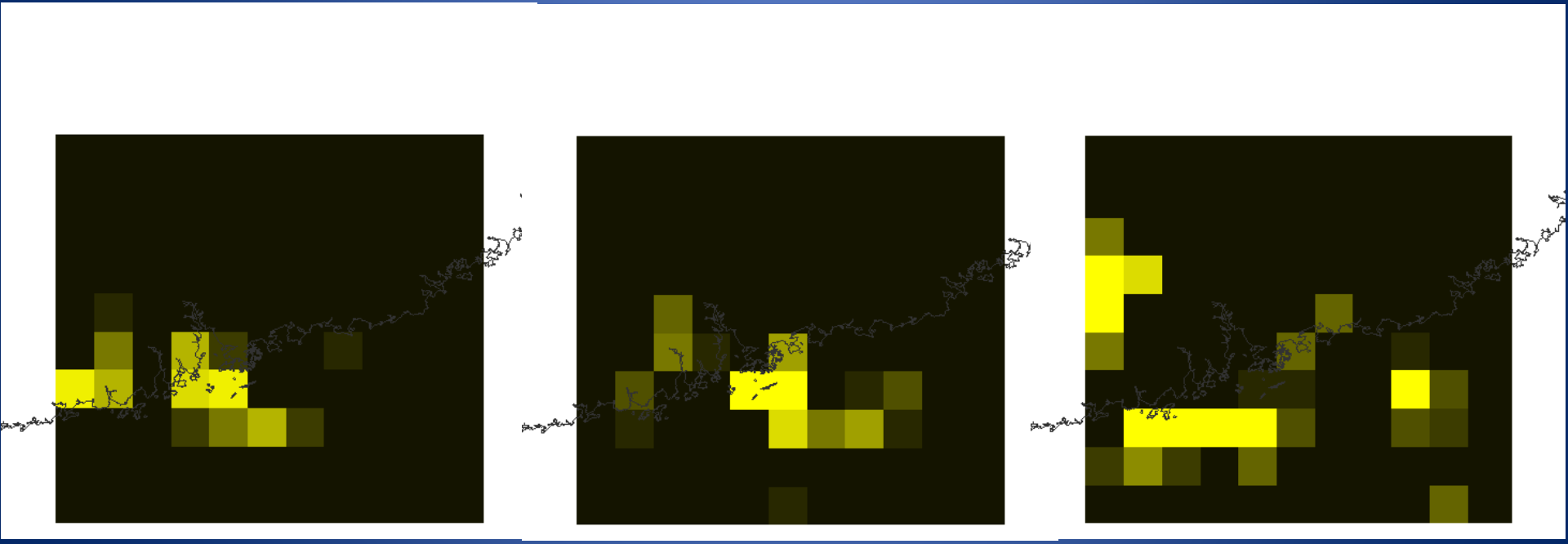


Grid of ~20NM radius (2hr forecast shown)

Radar

Nowcast

NWP



Merging/Blending/Mixing/Crossover to get advantage of both sides (?)

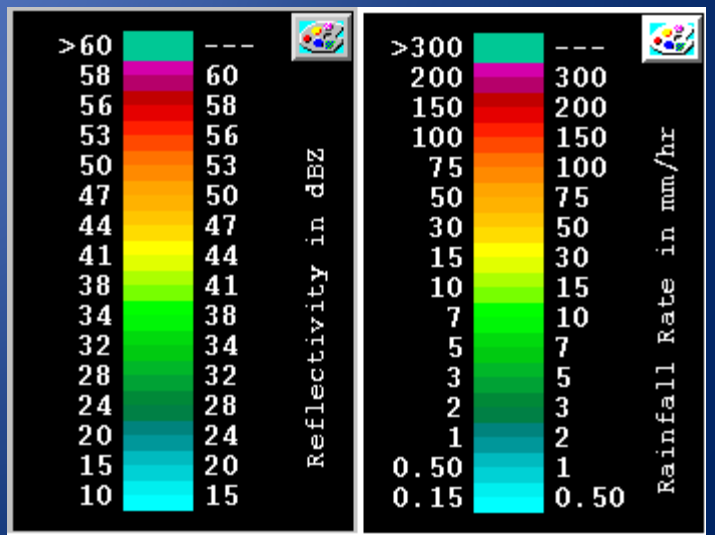
1. Choose a suitable horizontal scale
   - model forecast position error
   - uncertainty of motion vectors
2. **Extract the right information from NWP**
   - **surface parameter or data aloft**

Getting convection information from NWP

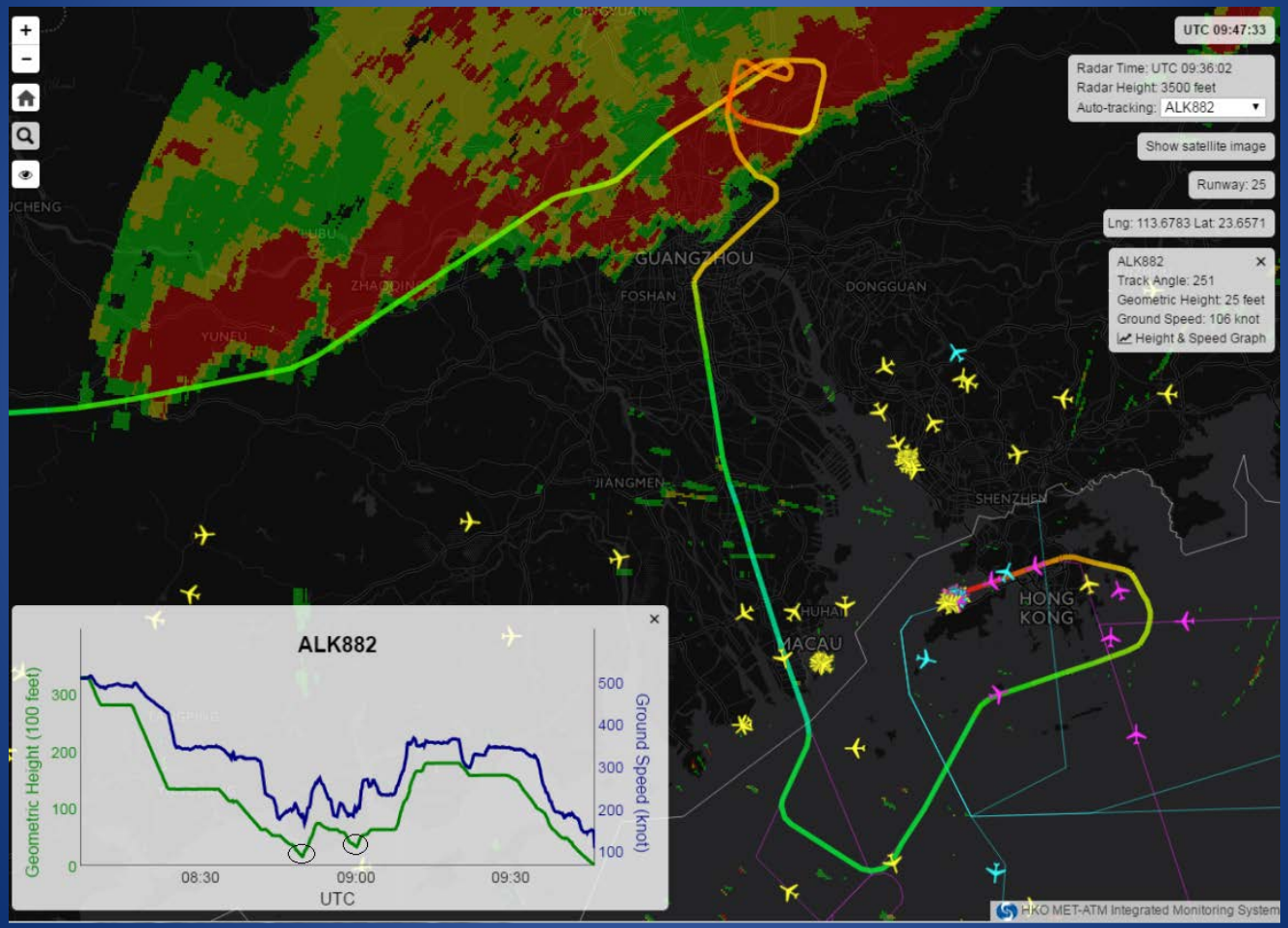
- Surface rainfall convert back to radar reflectivity using

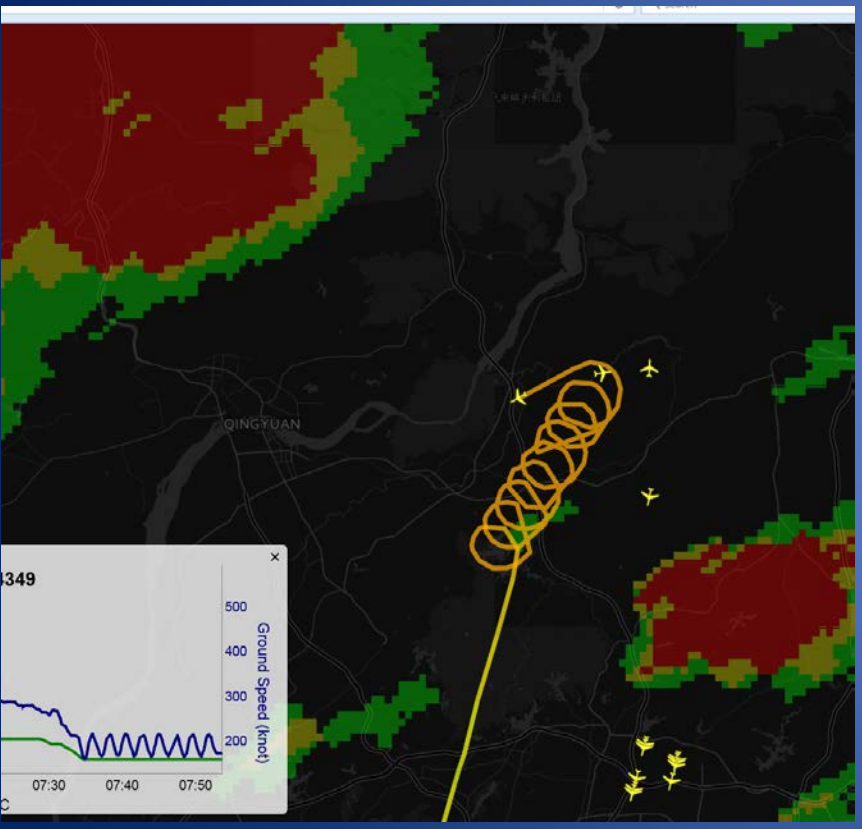
$$\frac{\text{mm}}{\text{hr}} = \left(\frac{10^{(dBZ/10)}}{200}\right)^{\frac{5}{8}}$$

- But it does not represent weather aloft



pilots concerns about weather aloft




QINGYUAN
4349
500
400
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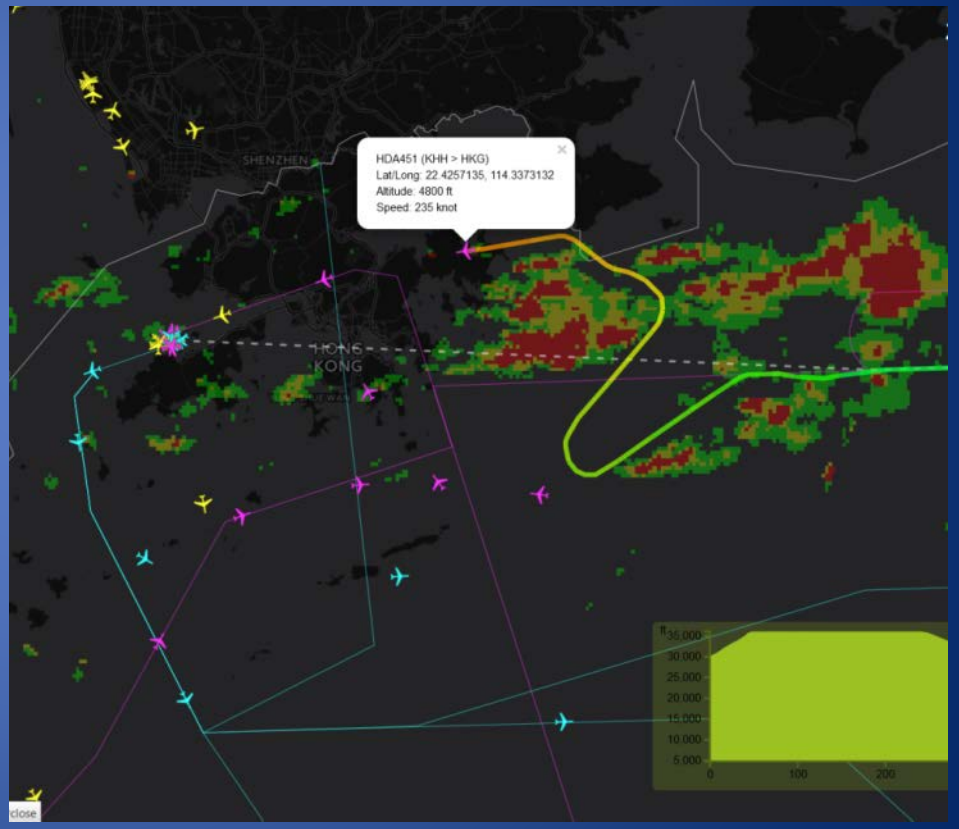
200
Ground Speed (knot)
07:30
07:40
07:50


SHENZHEN
HDA451 (KHH > HKG)
Lat/Long: 22.4257135, 114.3373132
Altitude: 4800 ft
Speed: 235 knot
HONG KONG
ft
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
100
200
close

and HKO's 2KM model is capable of generating these

$$Z = Z_r + Z_s + Zg$$

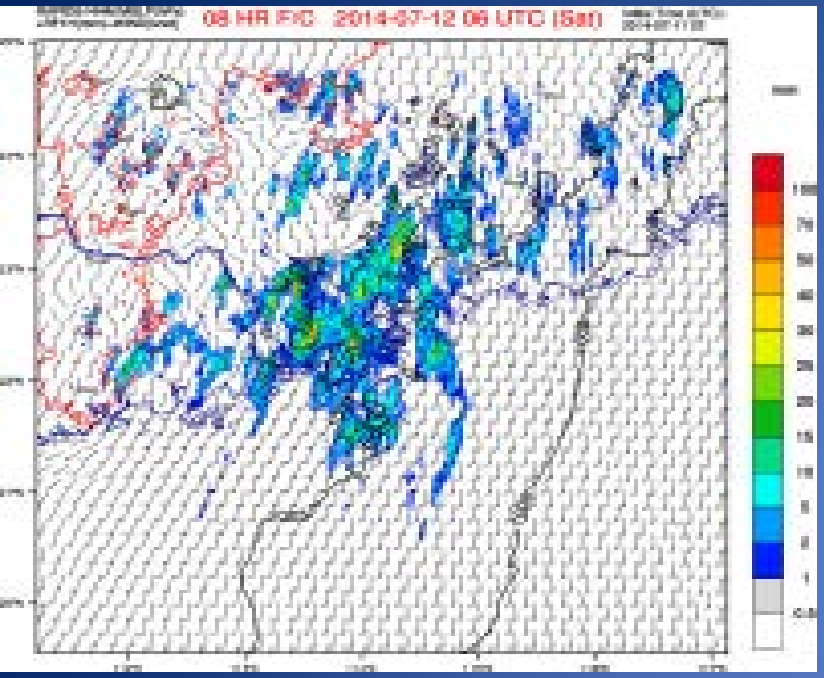
where

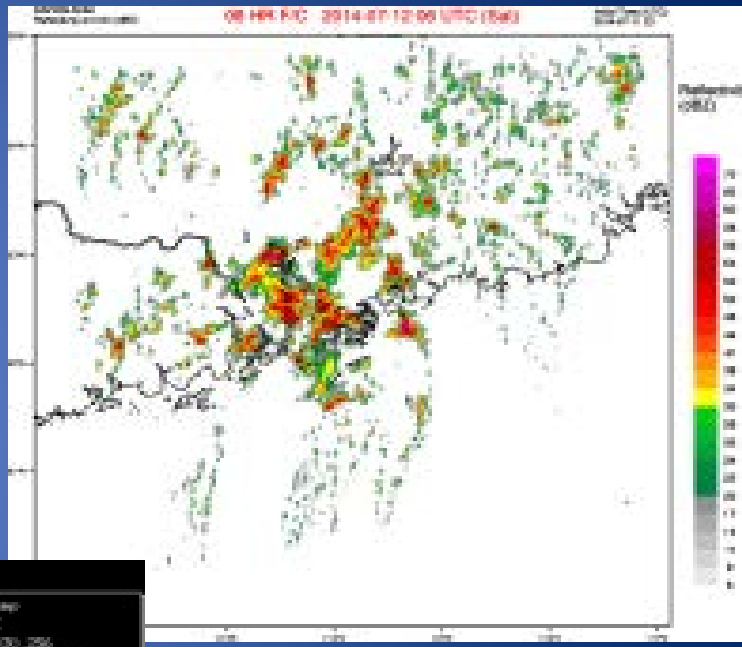
$$Z_r = 720 \frac{N_r}{\lambda_r^7}$$

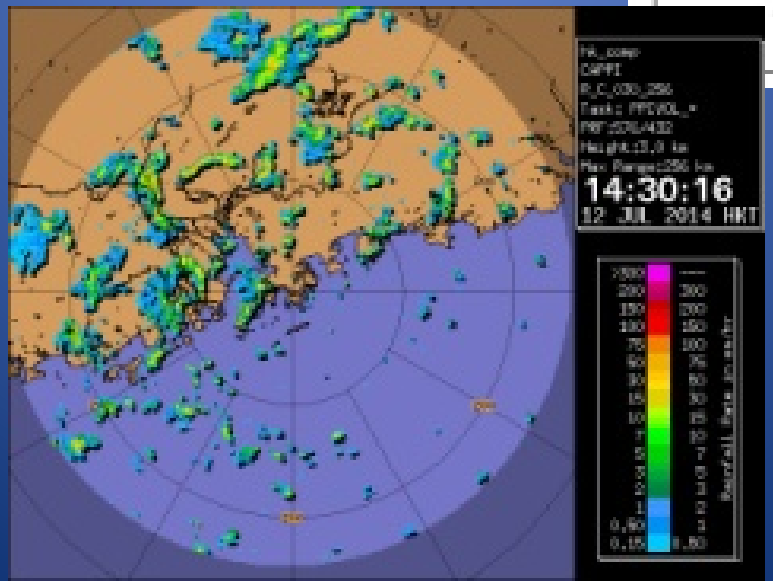
$$Z_s = 720 \frac{|K_i|^2}{|K_w|^2} \frac{\rho_s^2}{\rho_i^2} \frac{N_{os}}{\lambda_s^7}$$

$$Z_g = 720 \frac{|K_i|^2}{|K_w|^2} \frac{\rho_g^2}{\rho_i^2} \frac{N_{og}}{\lambda_g^7}$$

Rainfall vs Simulated radar reflectivity





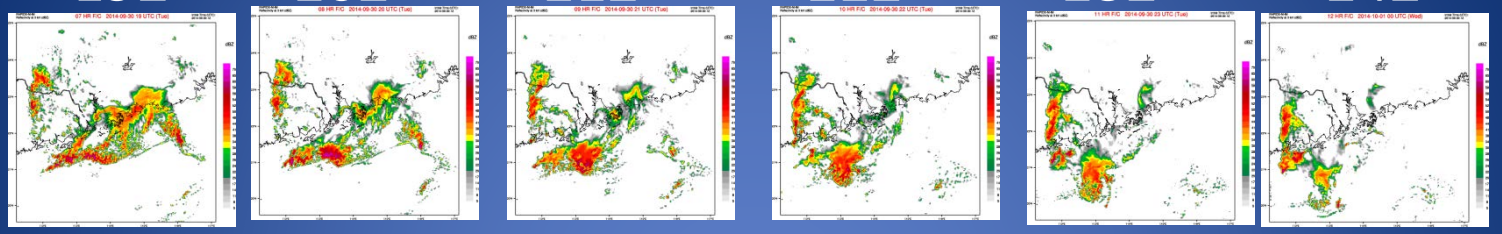


Merging/Blending/Mixing/Crossover to get advantage of both sides (?)

1. Choose a suitable horizontal scale
   - model forecast position error
   - uncertainty of motion vectors
2. **Extract the right information from NWP**
   - **surface parameter or data aloft**
   - **intensity vs intensity trend**

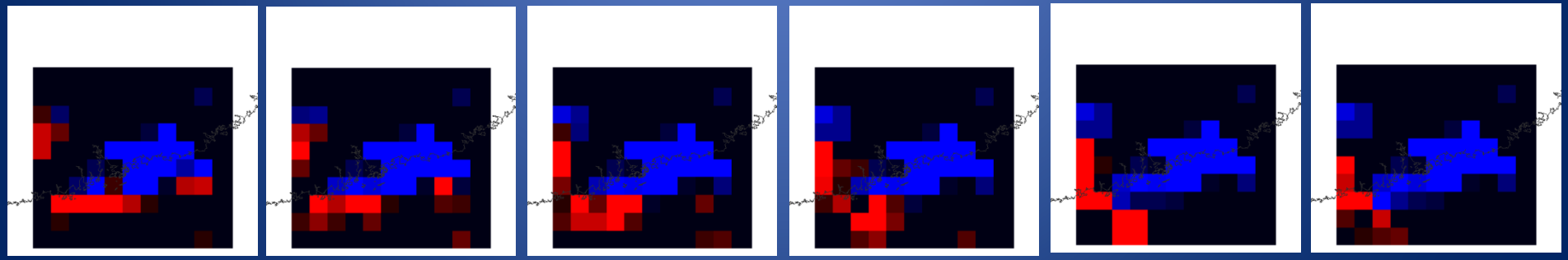
Absolute or Relative
(value or Δvalue)

19Z 20Z 21Z 22Z 23Z 24Z



- Use the information of “change” from NWP

19Z 20Z 21Z 22Z 23Z 24Z

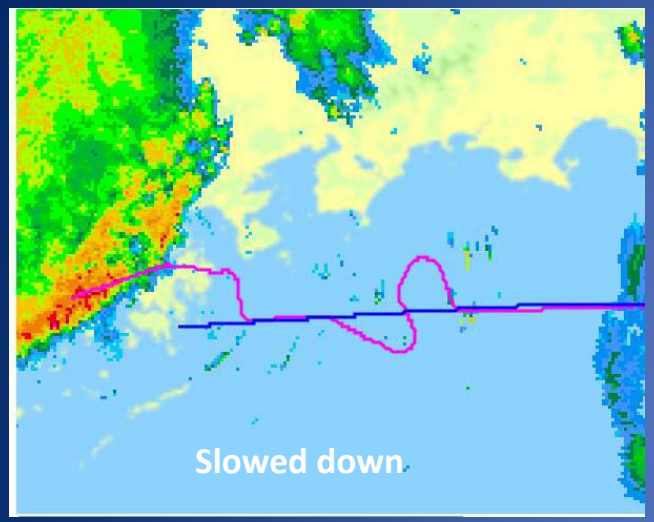


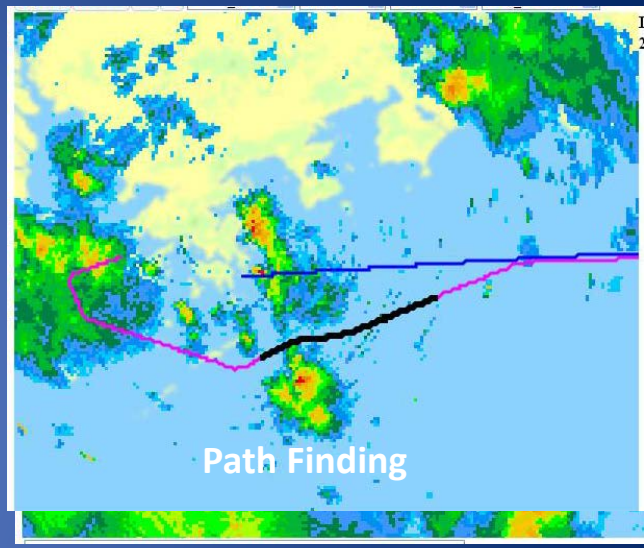
+1hr +2hr +3hr +4hr +5hr +6hr

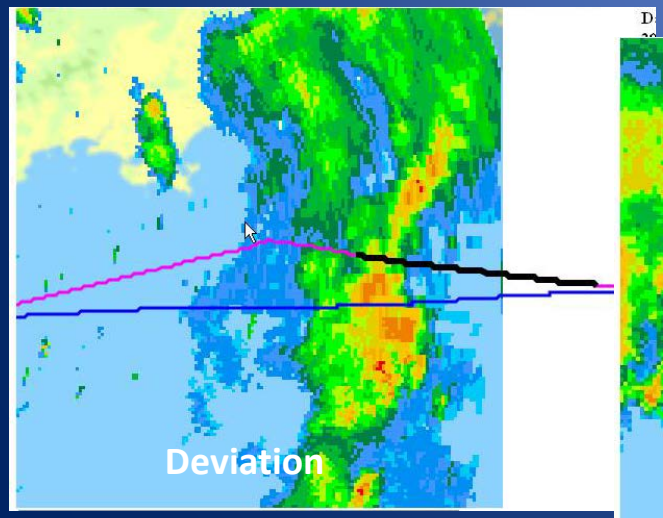
Merging/Blending/Mixing/Crossover to get advantage of both sides (?)

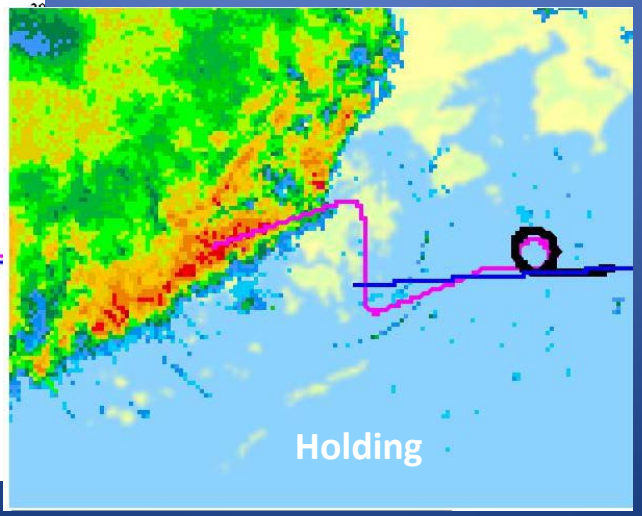
1. Choose a suitable horizontal scale
   - model forecast position error
   - uncertainty of motion vectors
2. Extract the right information from NWP
   - surface parameter (QPF) or water aloft (REF, VIL,VII…etc)
   - intensity or intensity change
   - **defining the thresholds (relates to operation)**

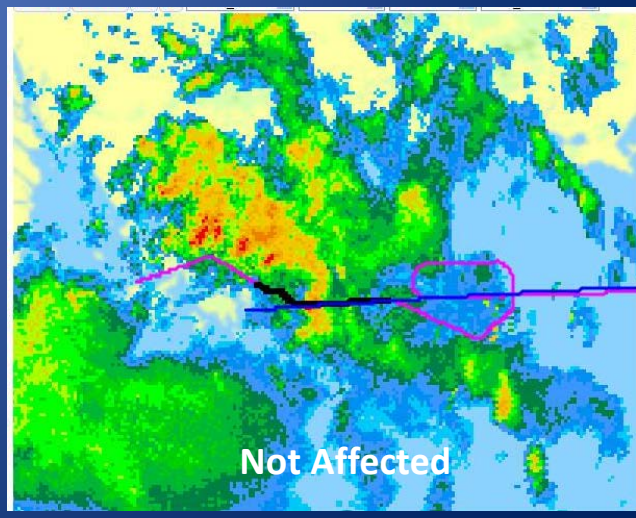
What threshold brings impact?
type of response towards convection



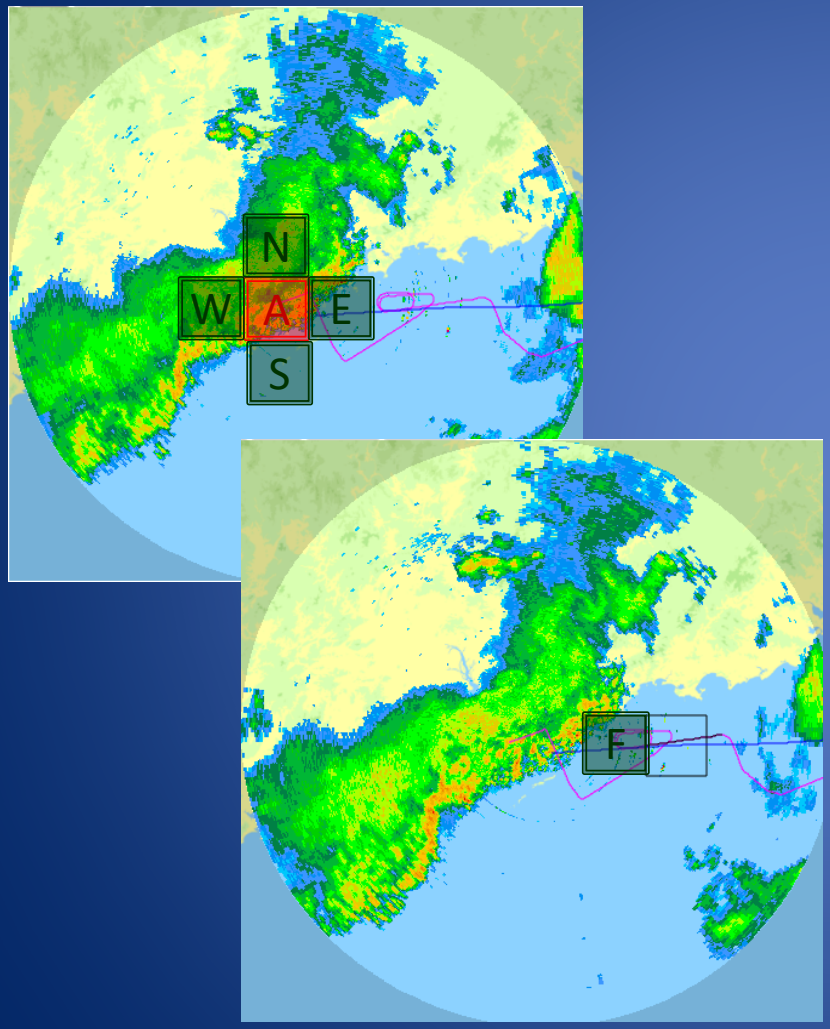


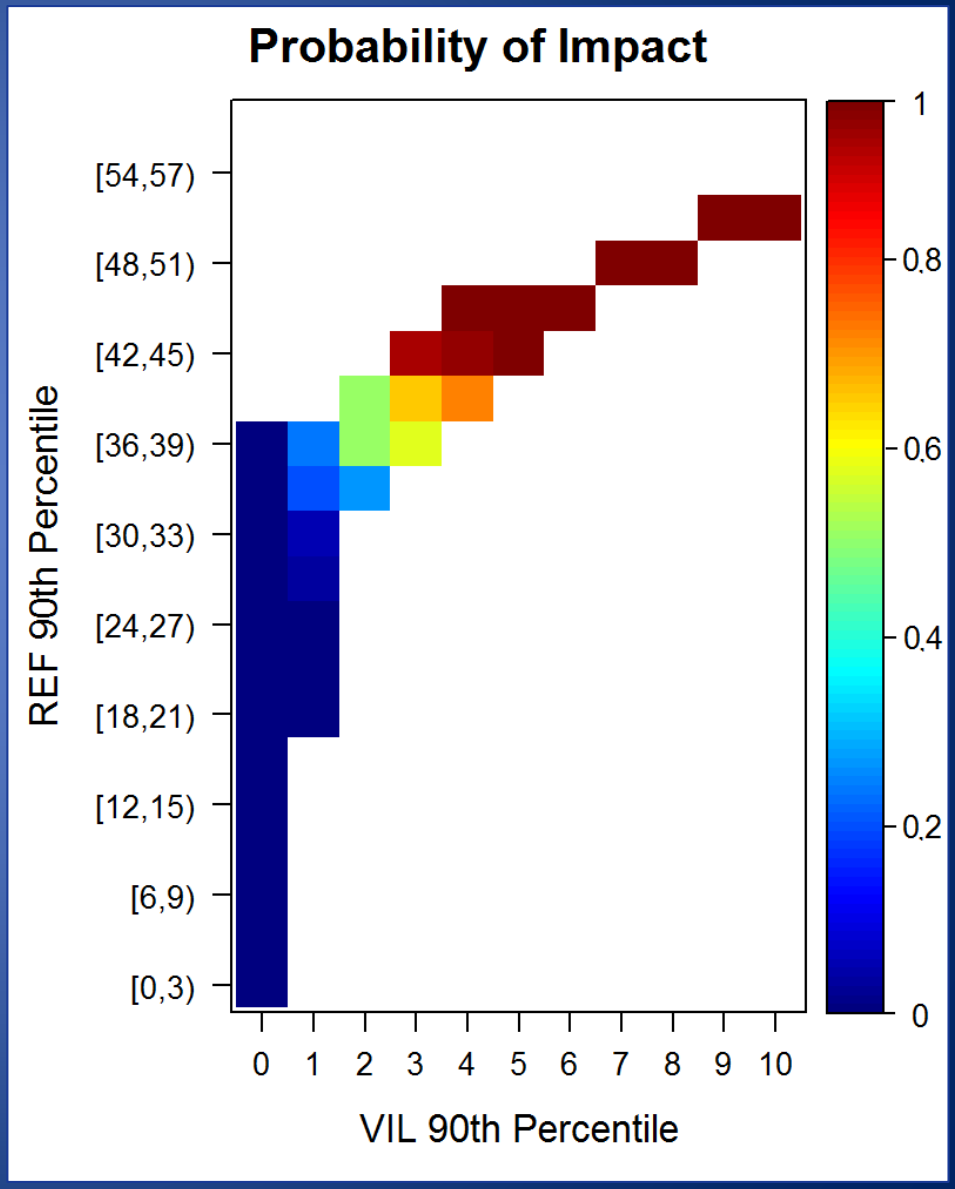






Severity and impact





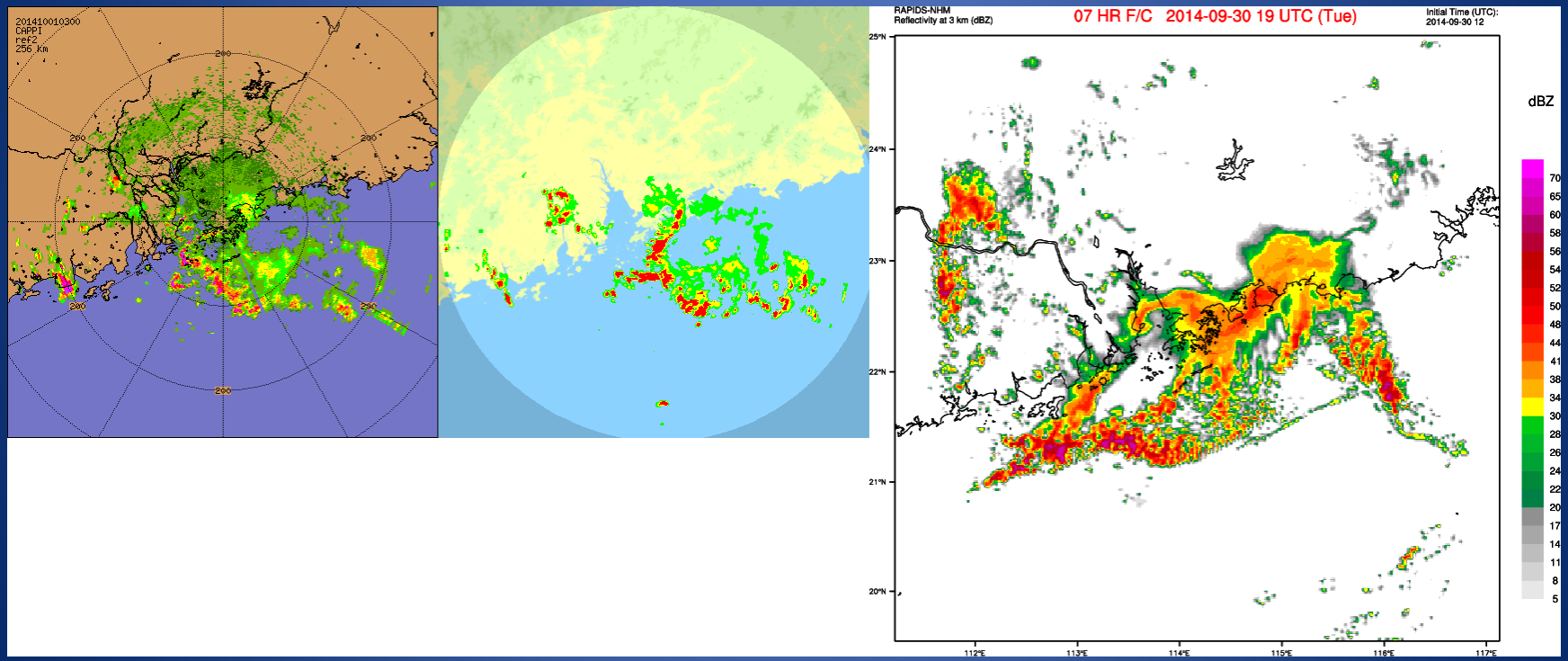
Thresholds of concern

- Impact depends on coverage of high return cells in the area of interest, where “high return” are chosen to be :
  - 33 dBZ for medium impact
  - 41 dBZ for large impact
- 5% coverage is under testing, but adjustable
- Termed “Amber” and “Red” impact

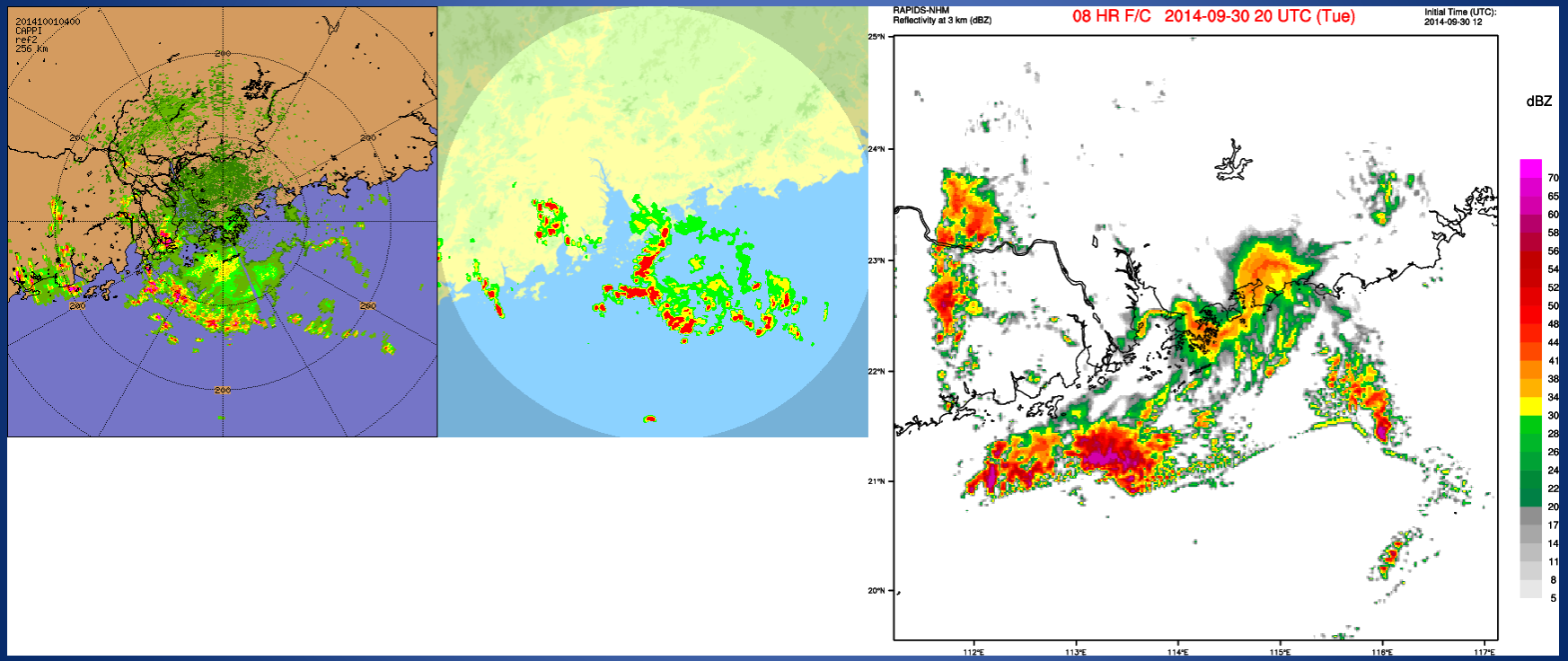
Merging/Blending/Mixing/Crossover to get advantage of both sides (?)

1. Choose a suitable horizontal scale
   - model forecast position error
   - uncertainty of motion vectors
2. Extract the right information from NWP
   - intensity vs intensity trend
   - surface parameter (QPF) or water aloft (ref, VIL,VII…etc)
   - defining the thresholds (relates to operation)
3. **Select the weighting in time**
   - **blend the nowcast and NWP depend on their performance w.r.t. forecast lead time**

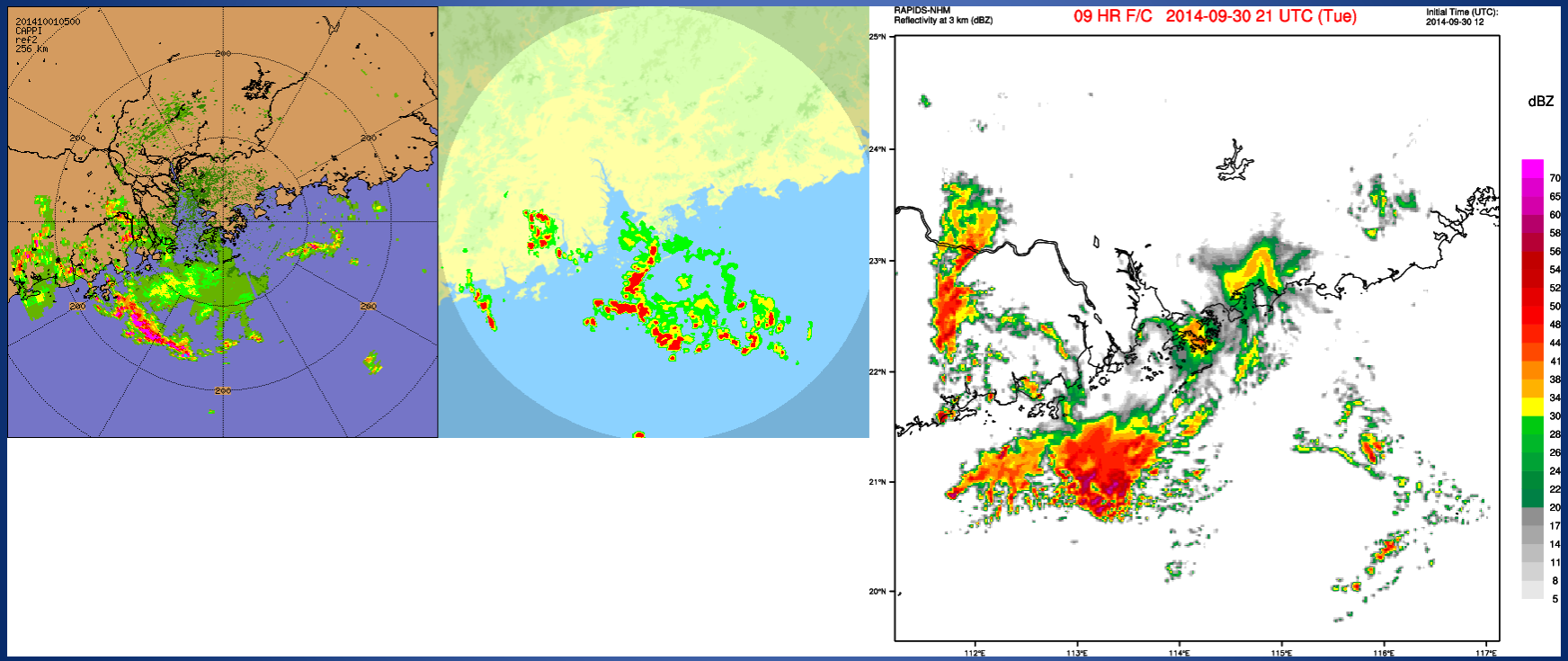
19Z, +1hr


201410010300
CAPPI
ref2
256 km
RAPIDS-NHM
Reflectivity at 3 km (dBZ)
07 HR F/C 2014-09-30 19 UTC (Tue)
Initial Time (UTC):
2014-09-30 12
dBZ
25°N
24°N
23°N
22°N
21°N
20°N
112°E
113°E
114°E
115°E
116°E
117°E

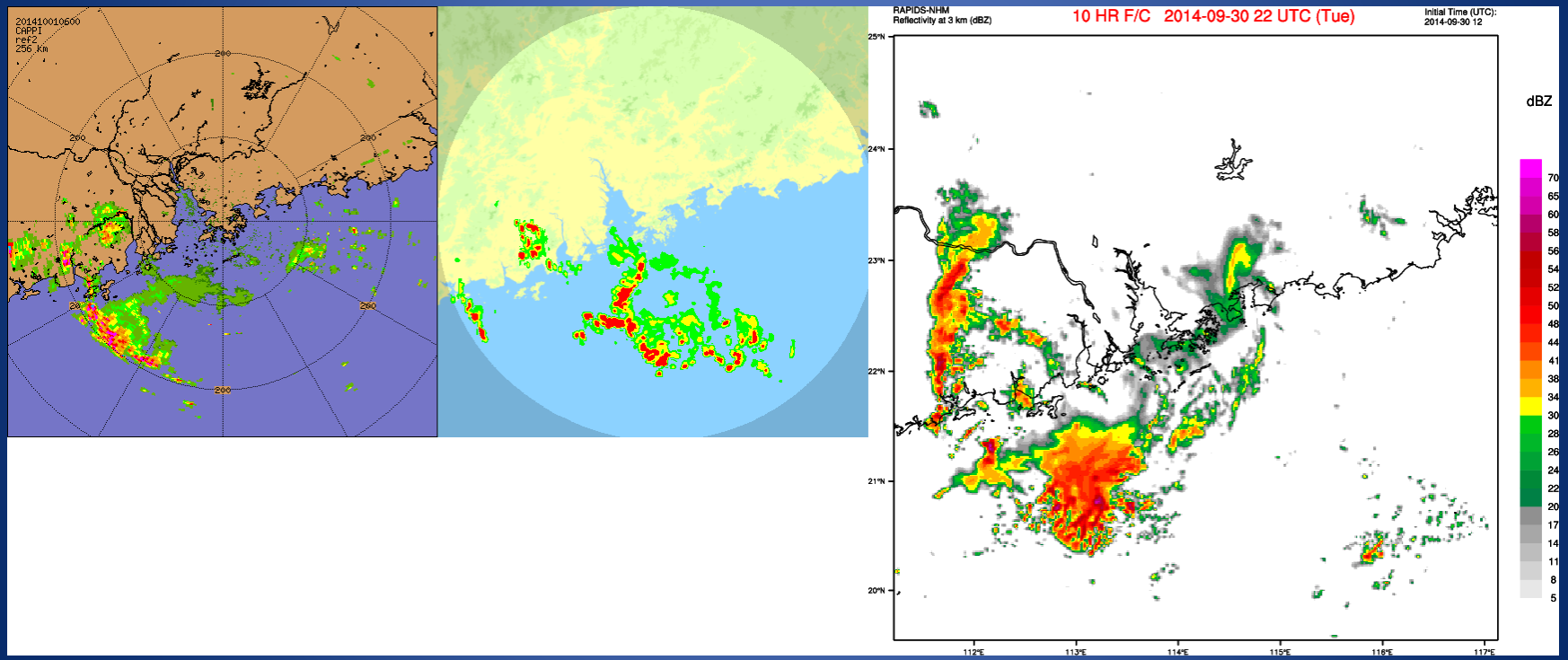
20Z, +2hr


201410010400
CAPPI
ref2
256 km
RAPIDS-NHM
Reflectivity at 3 km (dBZ)
08 HR F/C 2014-09-30 20 UTC (Tue)
Initial Time (UTC):
2014-09-30 12
dBZ
25°N
24°N
23°N
22°N
21°N
20°N
112°E
113°E
114°E
115°E
116°E
117°E

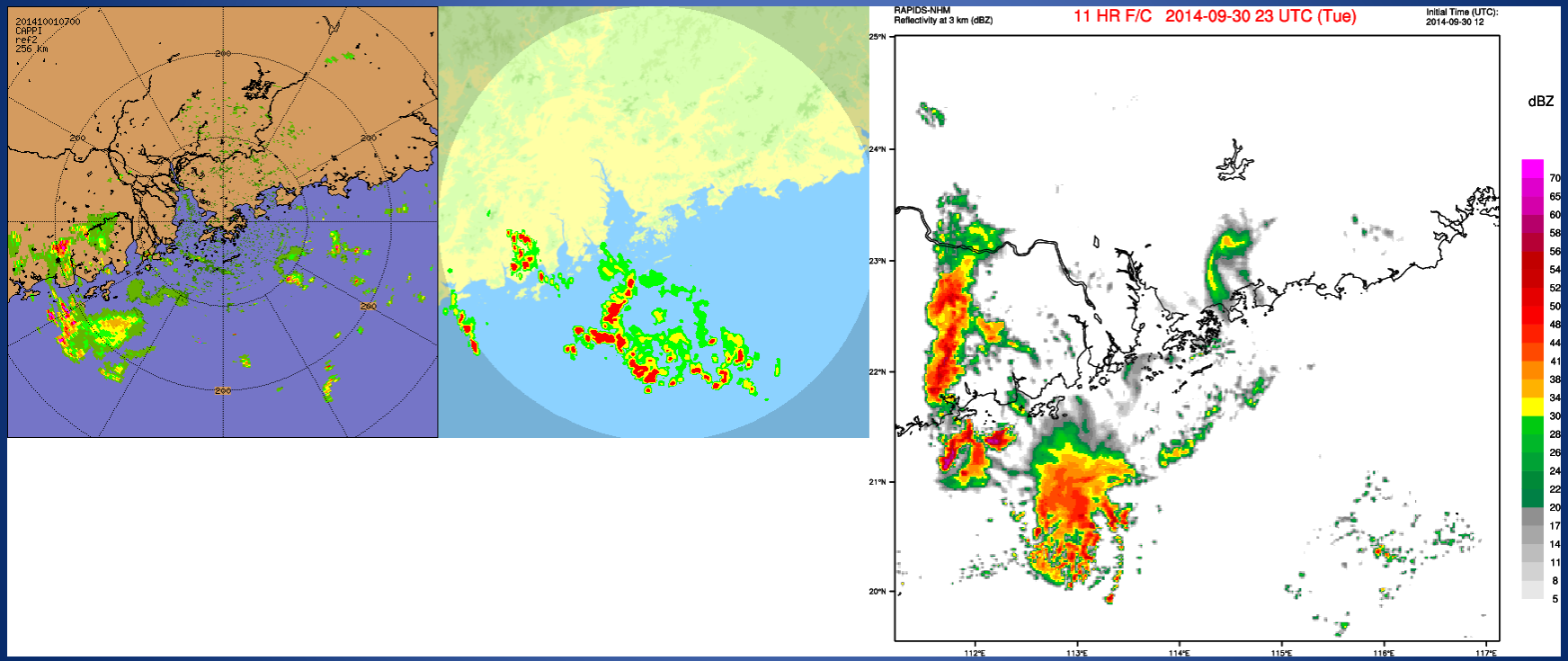
21Z, +3 hr


201410010500
CAPPI
ref2
256 km
RAPIDS-NHM
Reflectivity at 3 km (dBZ)
09 HR F/C 2014-09-30 21 UTC (Tue)
Initial Time (UTC):
2014-09-30 12
dBZ
25°N
24°N
23°N
22°N
21°N
20°N
112°E
113°E
114°E
115°E
116°E
117°E

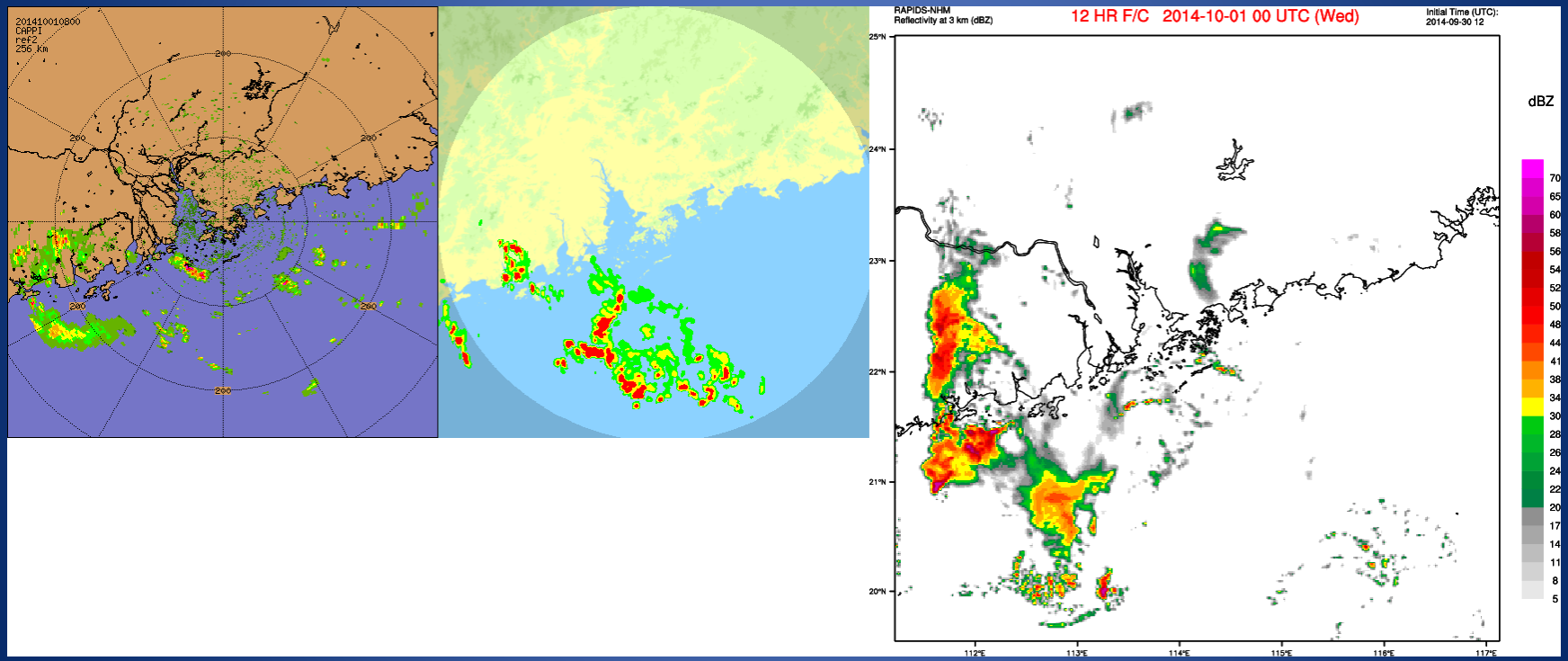
22Z, +4 hr


201410010600
CAPPI
ref2
256 km
RAPIDS-NHM
Reflectivity at 3 km (dBZ)
10 HR F/C 2014-09-30 22 UTC (Tue)
Initial Time (UTC):
2014-09-30 12
dBZ
25°N
24°N
23°N
22°N
21°N
20°N
112°E
113°E
114°E
115°E
116°E
117°E

23Z, +5hr


201410010700
CAPPI
ref2
256 km
RAPIDS-NHM
Reflectivity at 3 km (dBZ)
11 HR F/C 2014-09-30 23 UTC (Tue)
Initial Time (UTC):
2014-09-30 12
dBZ
25°N
24°N
23°N
22°N
21°N
20°N
112°E
113°E
114°E
115°E
116°E
117°E
70
65
60
58
56
54
52
50
48
44
41
38
34
30
28
26
24
22
20
17
14
11
8
5

24Z, +6hr


201410010800
CAPPI
ref2
256 km
RAPIDS-NHM
Reflectivity at 3 km (dBZ)
12 HR F/C 2014-10-01 00 UTC (Wed)
Initial Time (UTC):
2014-09-30 12
dBZ
25°N
24°N
23°N
22°N
21°N
20°N
112°E
113°E
114°E
115°E
116°E
117°E

How to blend?

- Nowcasting system from multi-sensor sources up to 9 hours forecast of radar reflectivity
- NWP (RAPIDS-NHM of HKO) simulated reflectivity
- Impact in terms of percentage coverage of 33/41dBZ;
- Calculate trend factor for areas of interest;
- Blending parameter (w) takes linear form decreasing from 1 to 0 in 6 hours
- Output the time-weighted mixture of two trend factors add to actual observation

Will it blend?

- Amber criteria for all zones over 6 hours

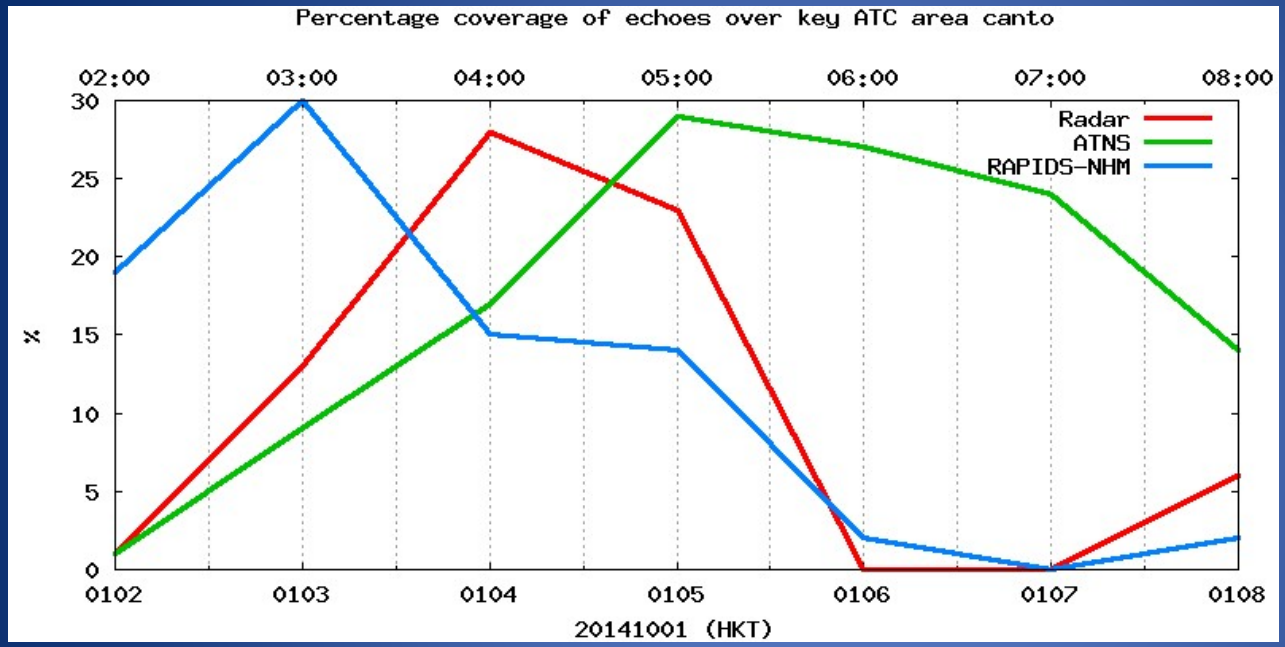
	Nowcast	RAPIDS-NHM	*Blended*
POD	0.5	0.88	***0.75***
FARatio	0.5	0.3	***0***
CSI	0.33	0.64	***0.75***

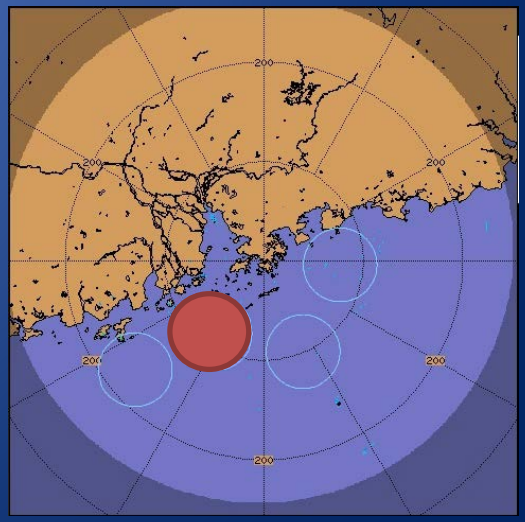
- Red criteria for all zones over 6 hours

	Nowcast	RAPIDS-NHM	*Blended*
POD	0.6	1.0	***0.8***
FARatio	0.57	0.44	***0.33***
CSI	0.33	0.56	***0.57***

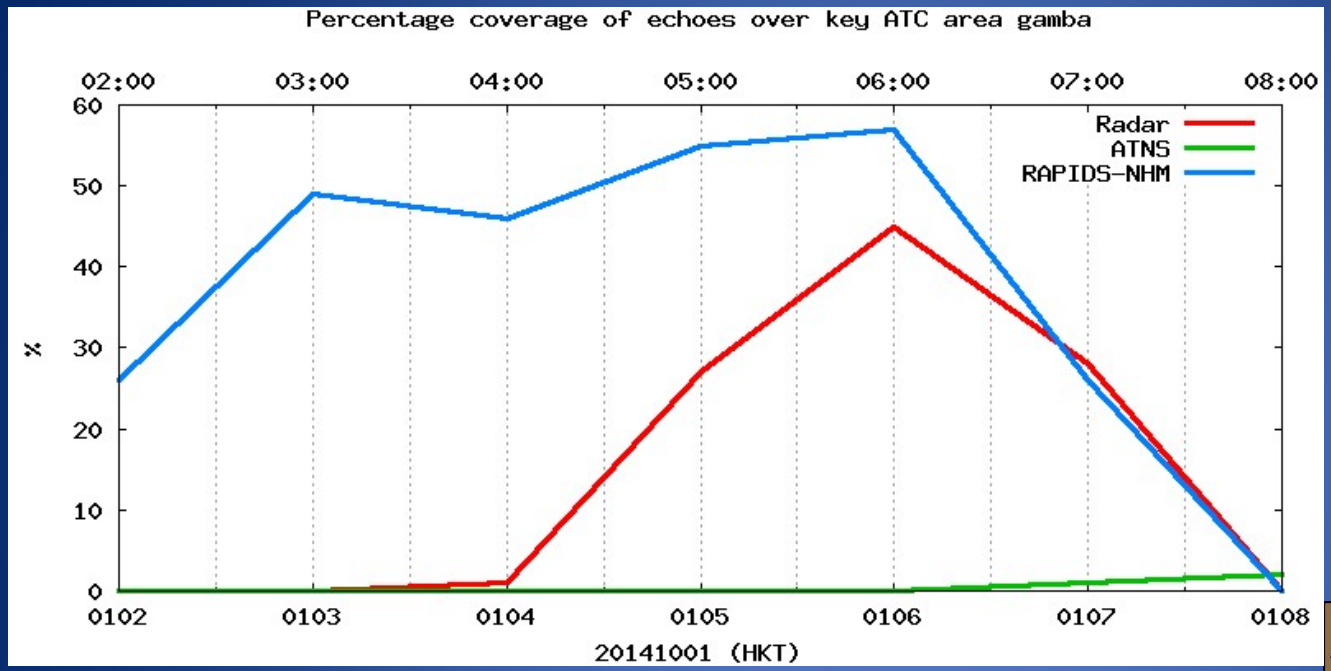
*** This is for only one case ***

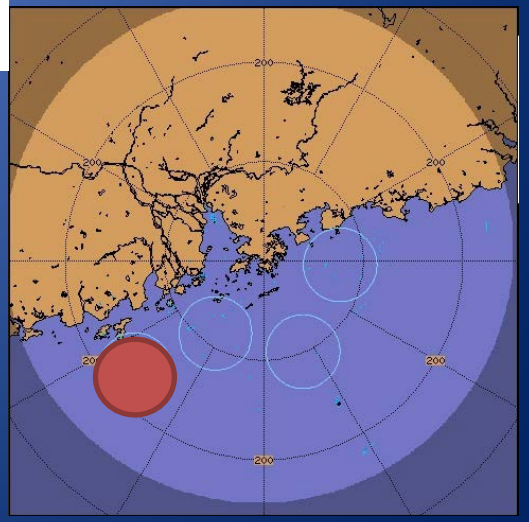
We have a case





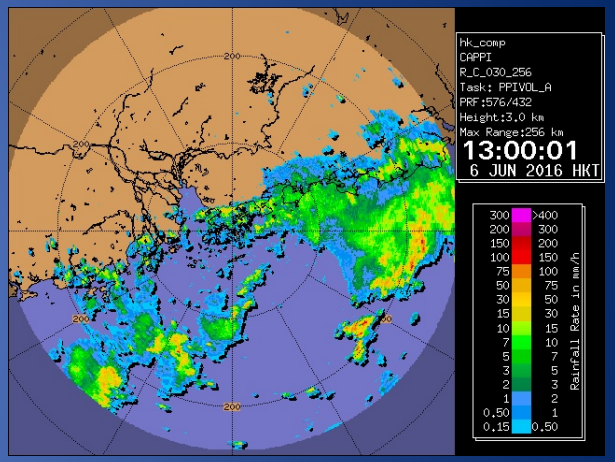
We have a case

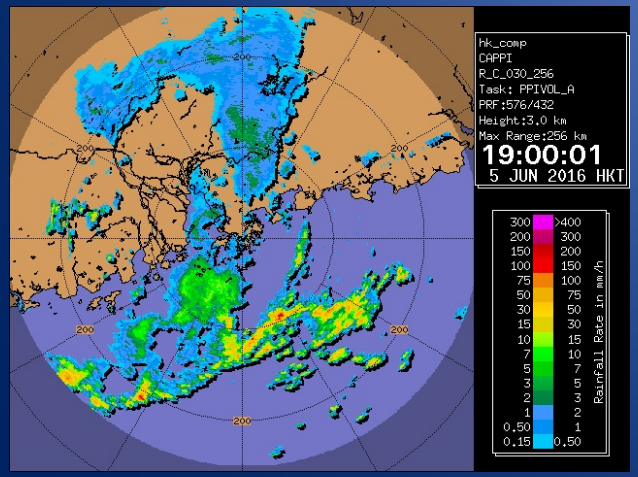


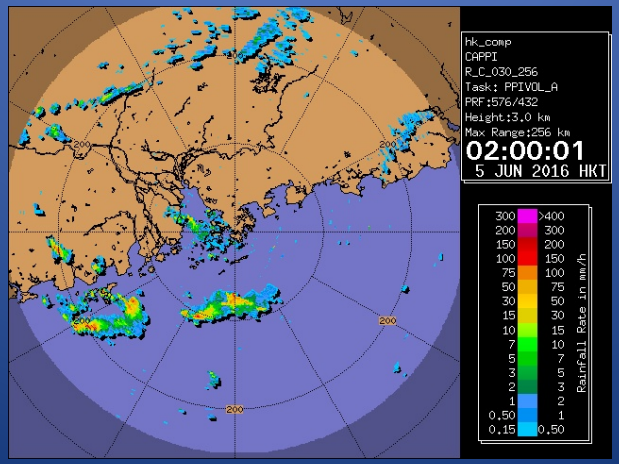


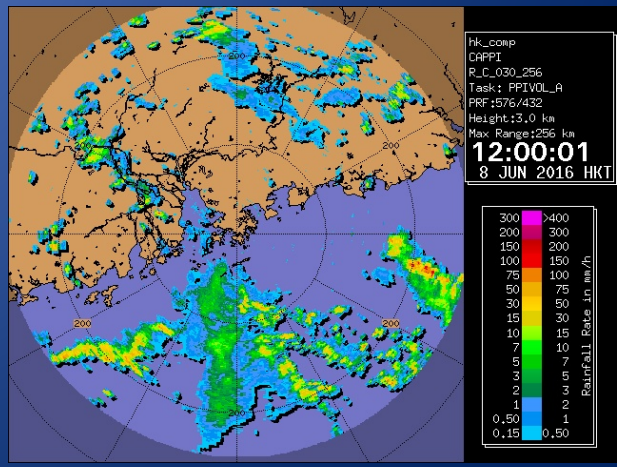
More realistic performance (1 – 10 June 2016)

- A continuous period of 10 days
  - 7 days having TS warnings
  - 2 days of rainstorm warning









More realistic performance (1 – 10 June 2016)

- CSI

F hour	Nowcast	RAPIDS-NHM	*Blended*
+1 hr	0.55	0.18	***0.58***
+2 hr	0.37	0.24	***0.41***
+3 hr	0.31	0.25	***0.42***
+4 hr	0.2	0.2	***0.32***
+5 hr	0.1	0.1	***0.25***
+6 hr	0.1	0.1	***0.16***

Nothing new, just how it was applied

- Key points:
  - satellite derived radar parameters merging with radar data to extend the nowcast domain (MSQ)
  - horizontal scale (20nm radius): 15min flight time, reasonable performance of NWP, typical size of holding zones
  - Variable: % coverage of **reflectivity above threshold** within the target area
  - The blending method: linear weighting of additive trend
- More options are being explored