Merging radar nowcast with convection-permitting rapidly-updated NWP model for significant convection forecast

Wai-kin WONG

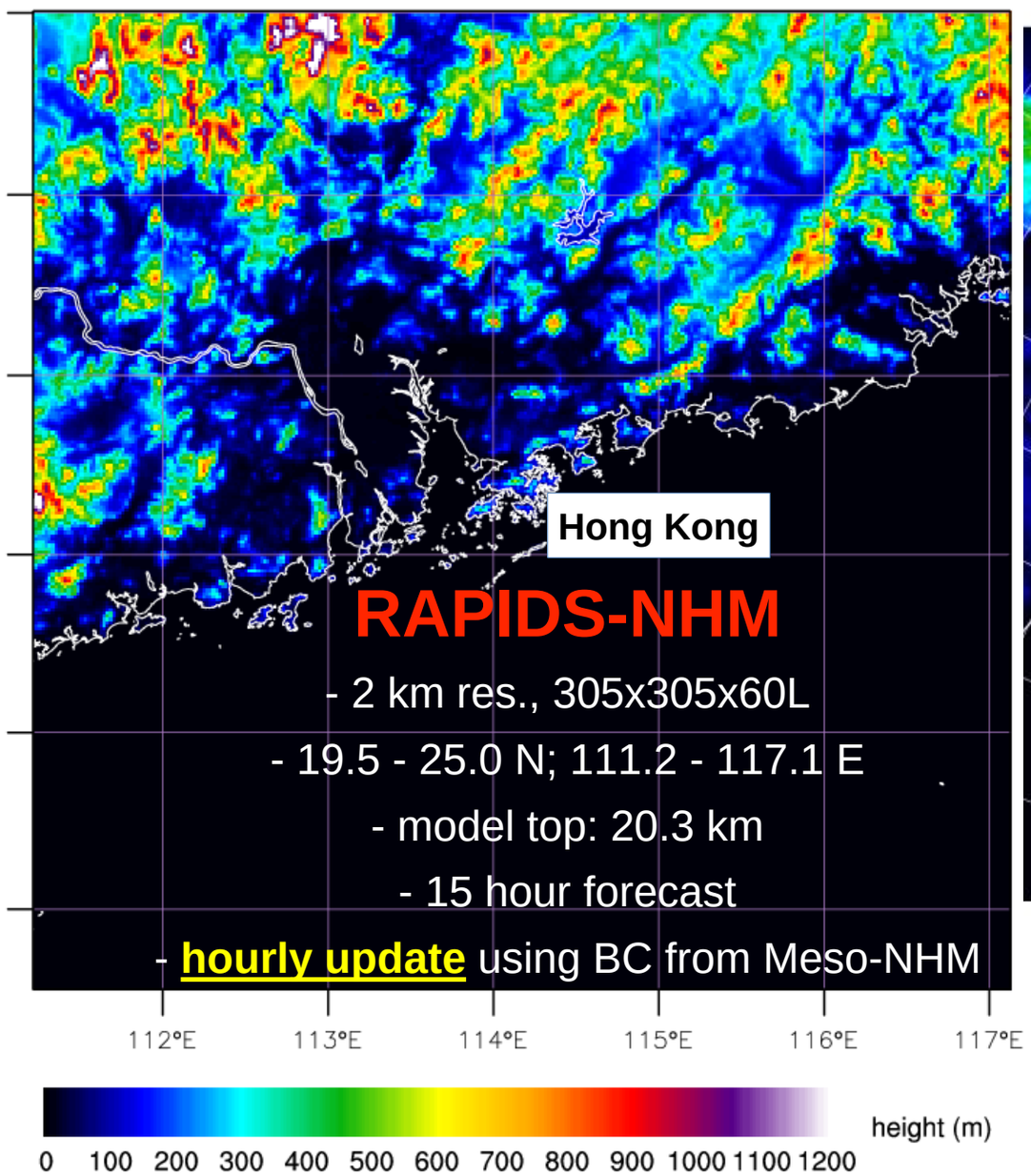
WMO WWRP 4th International Symposium on Nowcasting and Very-short-range Forecast 2016 (WSN16)

Session W2B, 27 July 2016

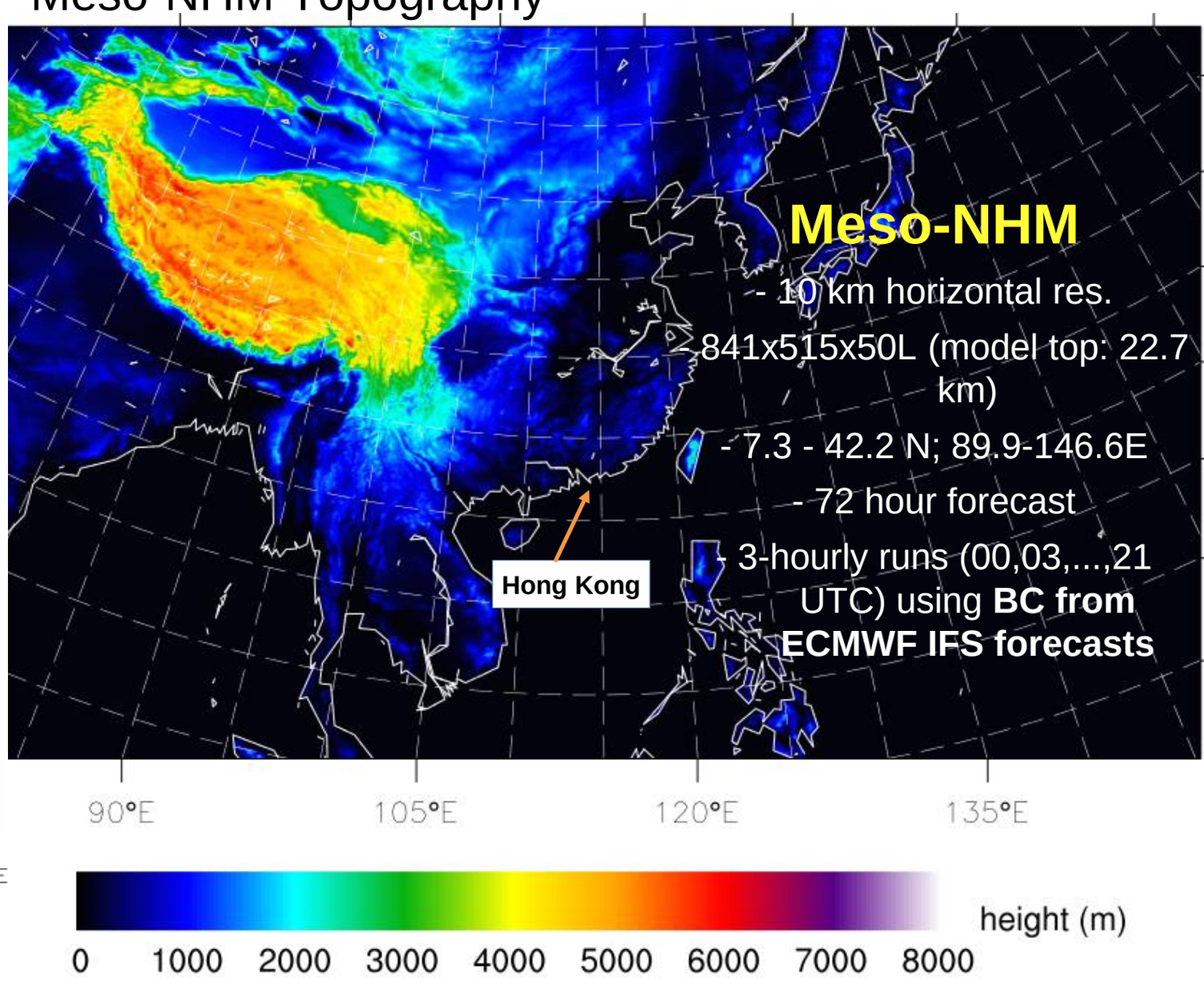
香港天文台
Hong Kong Observatory

Mesoscale and Convection Permitting NWP System of Hong Kong Observatory

RAPIDS-NHM Topography

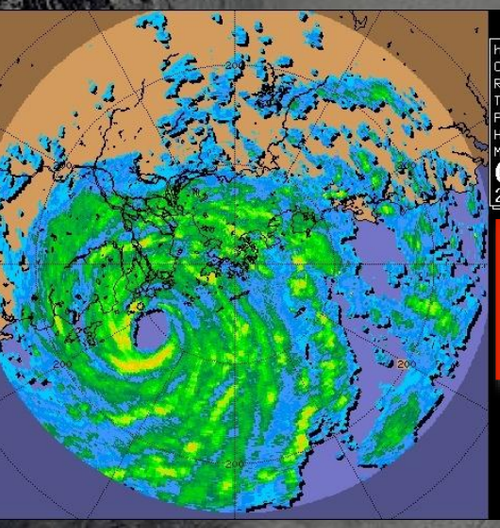


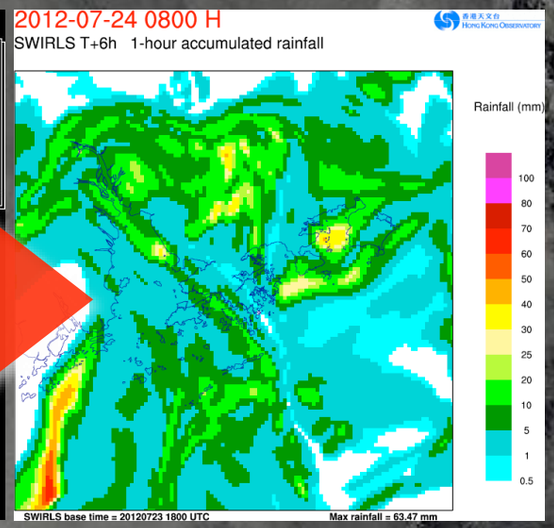
Meso-NHM Topography



Blending QPFs from Nowcast and NWP

ST Vicente (2012-07-24 02:00 HKT)



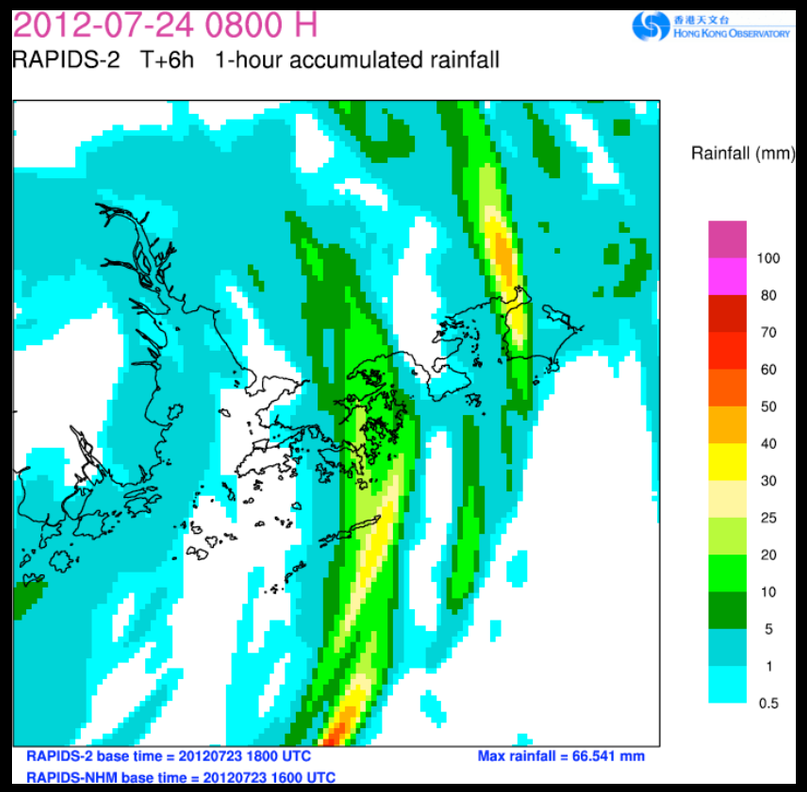


SWIRLS-2 radar nowcast (1-6 hr)

(optical flow tracking, semi-Lagrangian advection)

Blending

RAPIDS QPF



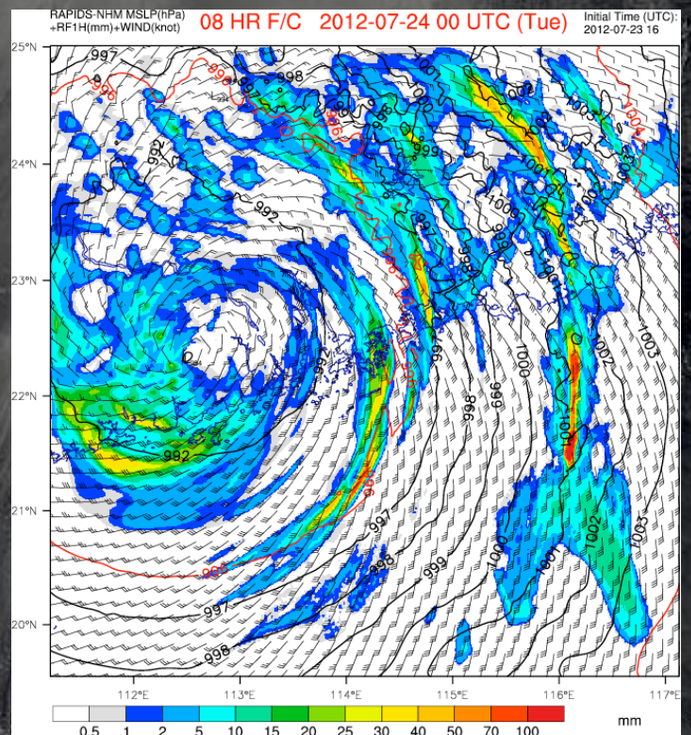
RAPIDS-NHM rainfall forecasts

(1-15 hr)

Reference:

http://www.weather.gov.hk/publica/reprint/r607.pdf

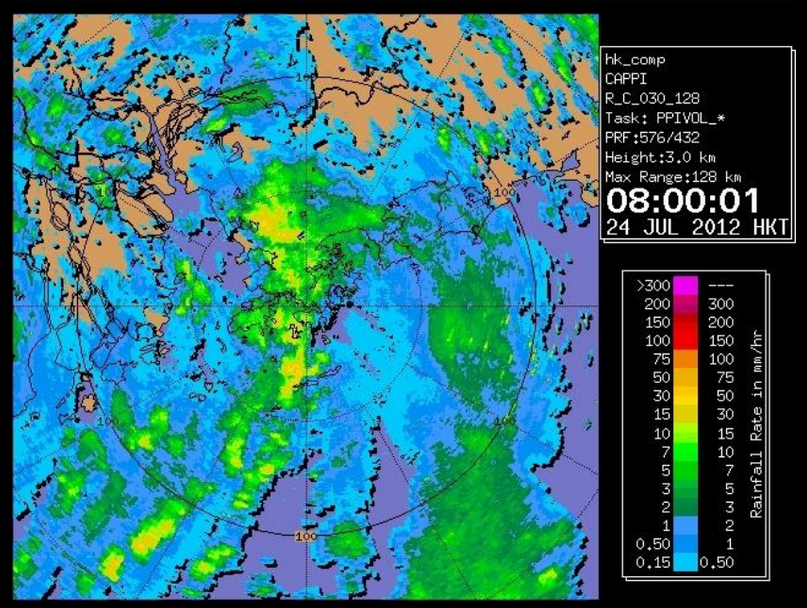
http://www.weather.gov.hk/publica/reprint/r844.pdf



Phase correction of position error of model QPF

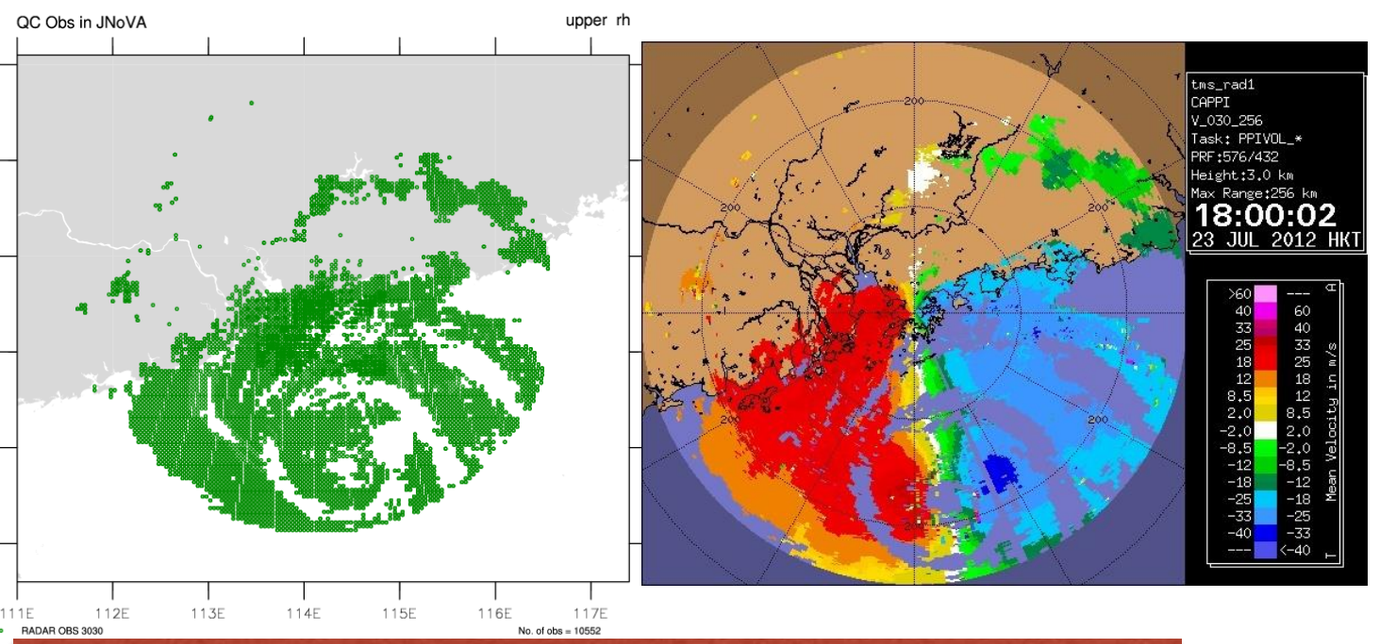
Intensity calibration to adjust model rainfall intensity

Superposition on radar nowcast using time-dependent weighting

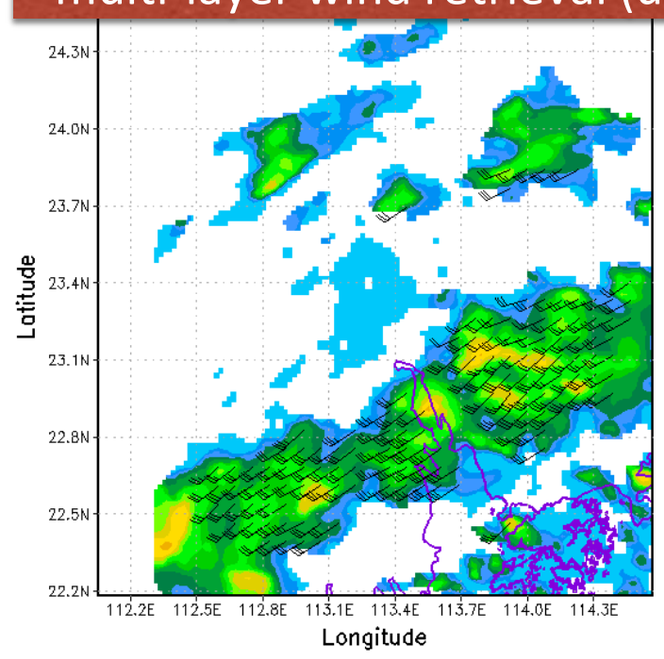


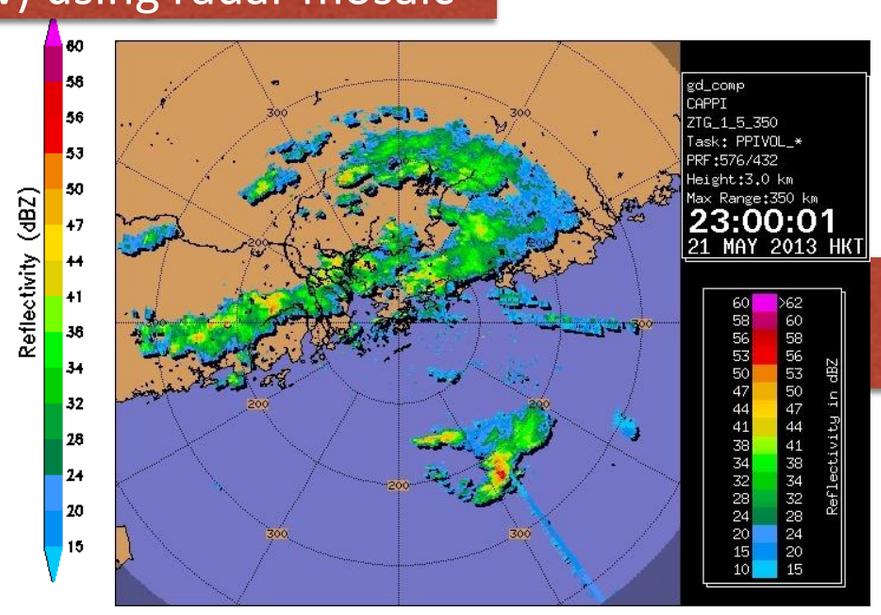
Data Assimilation of Radar Observations in RAPIDS-NHM

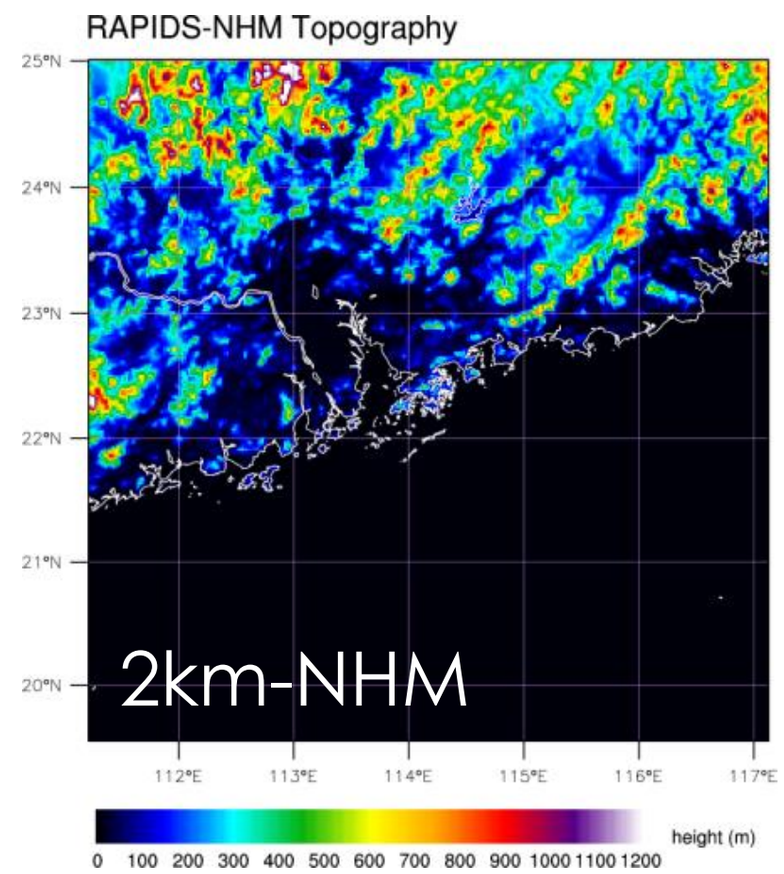
Doppler velocity from radars in HK



multi-layer wind retrieval (u,v) using radar mosaic







CAPPI reflectivity volume for 1D retrieval (mosaic from HK + Guangdong radars)

Phase correction based on optical flow

- Given RAPIDS-NHM QPF (~ T+1 - T+2h) and SWIRLS QPE valid at same forecast time:

$$\min: \quad J = \iint \left[\frac{\partial I}{\partial t} + u \frac{\partial I}{\partial x} + v \frac{\partial I}{\partial y} \right]^2_{NHM \rightarrow SWIRLS} dxdy$$

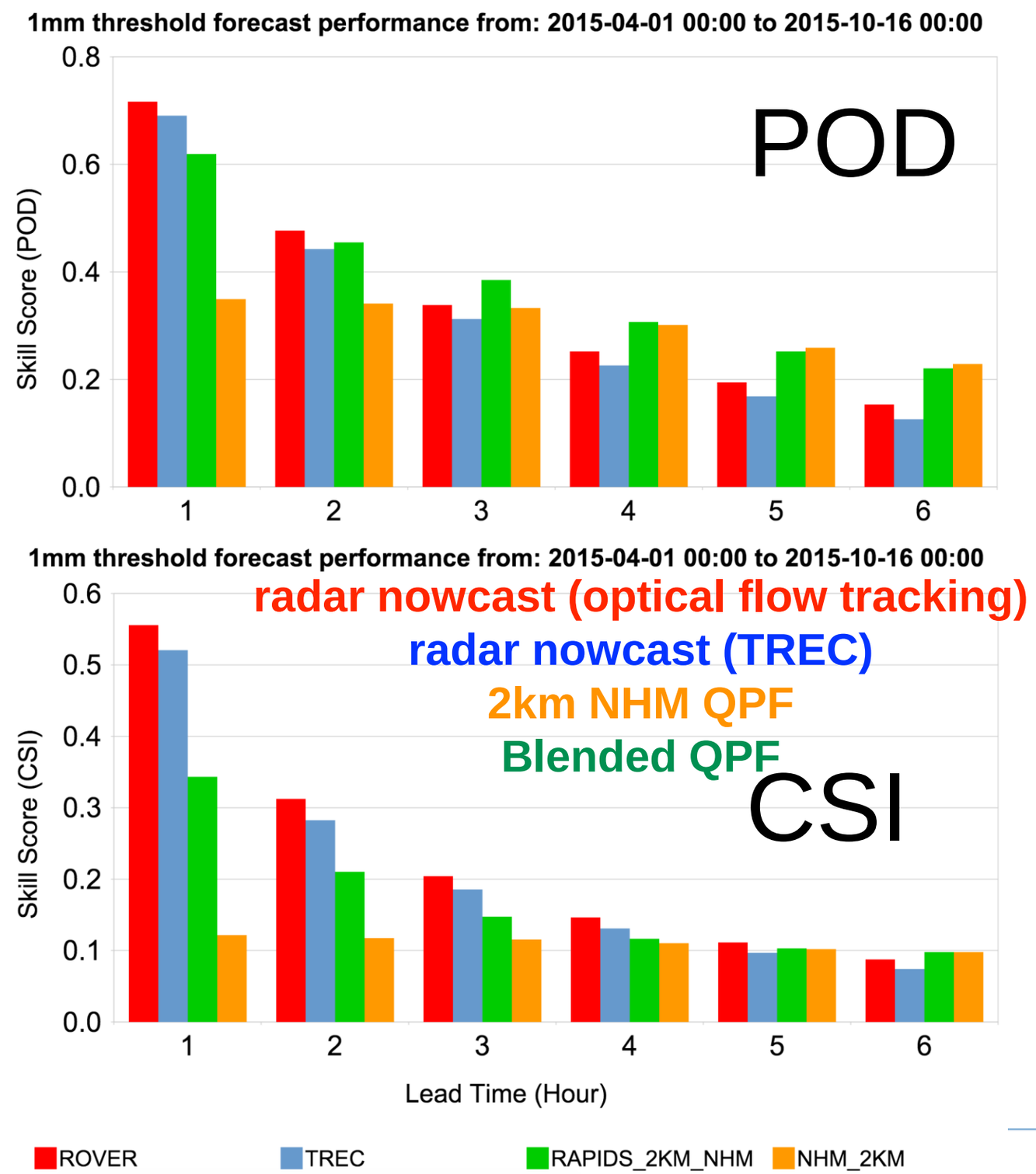
- A 10x10 block is used in regional phase correction to determine phase correction vector field (u,v)

- In RAPIDS, phase correction (and blending) is applied every 6 minutes.

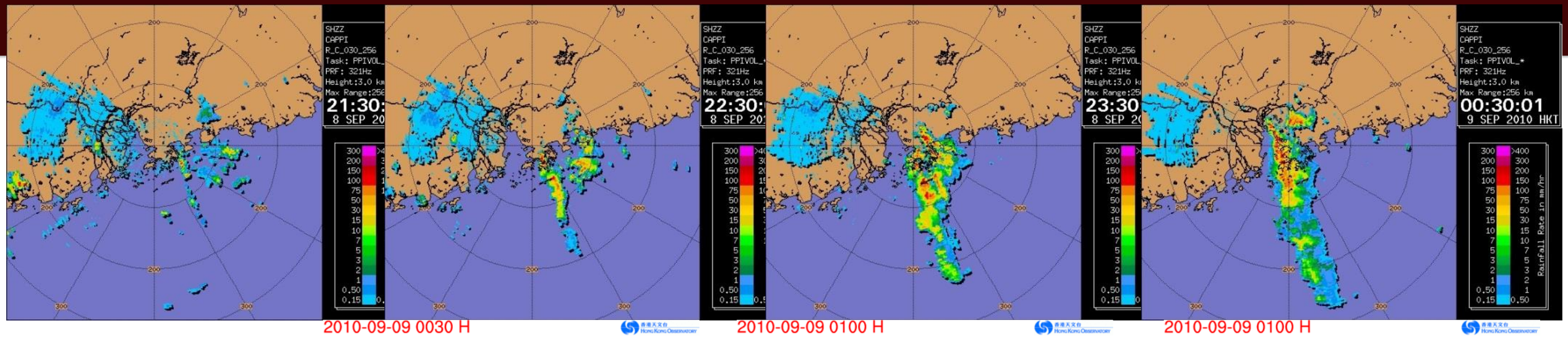
Verification (2015)

grid-by-grid verification of QPF (dx = 2 km)
over HK and Pearl River Delta

- Blending of radar nowcast and RAPIDS-NHM QPF
  - track motion of radar echoes over successive radar images and extrapolate for 6-9 hours
  - blending with RAPIDS-NHM QPF after correcting phase errors of gridded rainfall forecasts
  - blending of other convective forecast parameters (e.g. significant convection)



Flight diversion due to significant convection

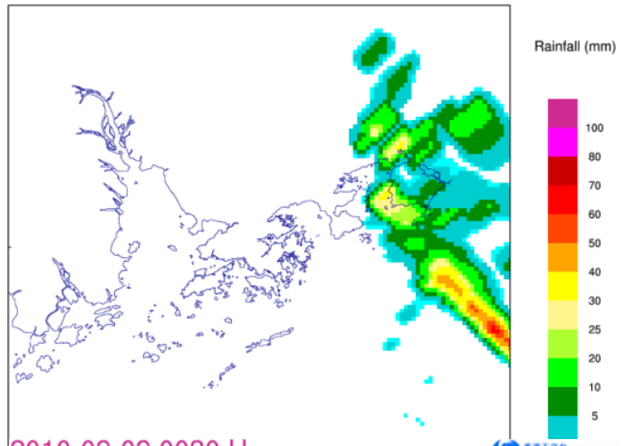


2010-09-09 0030 H
SWIRLS T+6h 1-hour accumulated rainfall

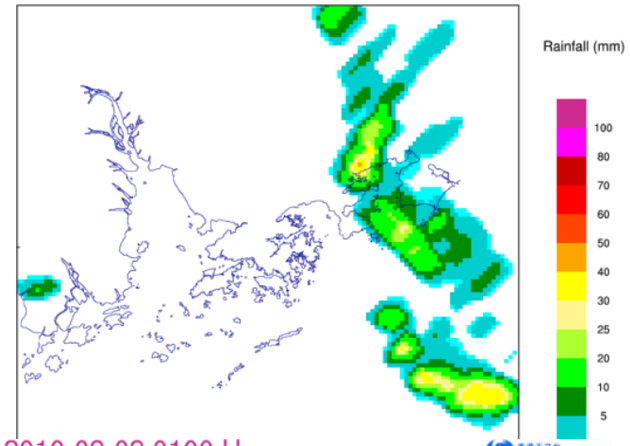
2010-09-09 0100 H
SWIRLS T+6h 1-hour accumulated rainfall

2010-09-09 0100 H
SWIRLS T+5h 1-hour accumulated rainfall

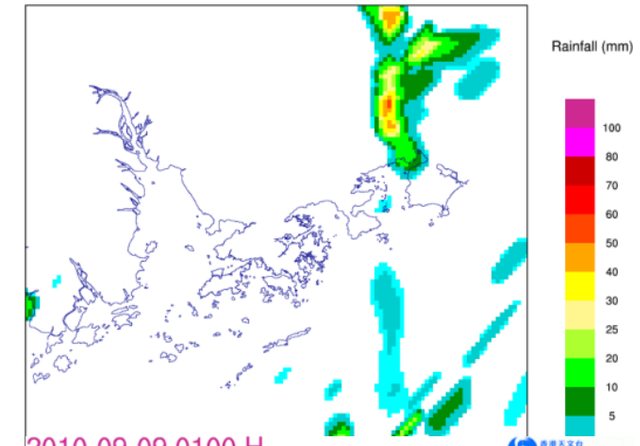
SWIRLS nowcasts for 00:30 – 01:00H



2010-09-09 0030 H
RAPIDS2k T+6h 1-hour accumulated rainfall



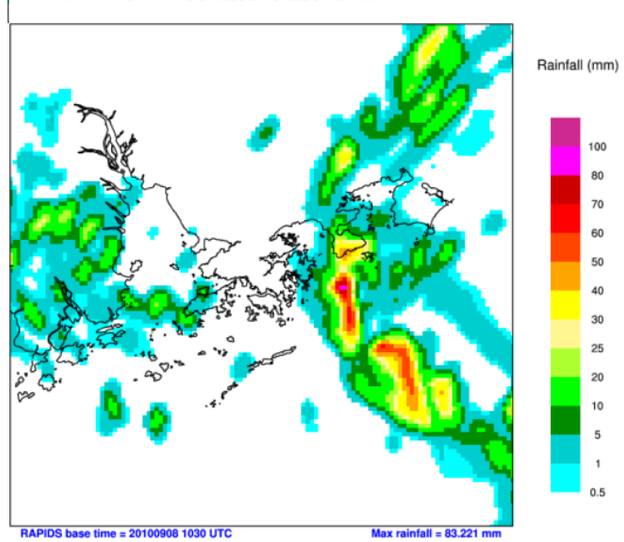
2010-09-09 0100 H
RAPIDS2k T+6h 1-hour accumulated rainfall

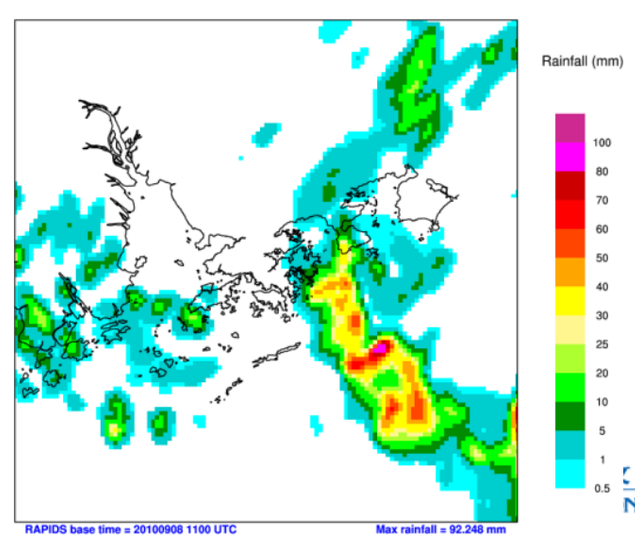


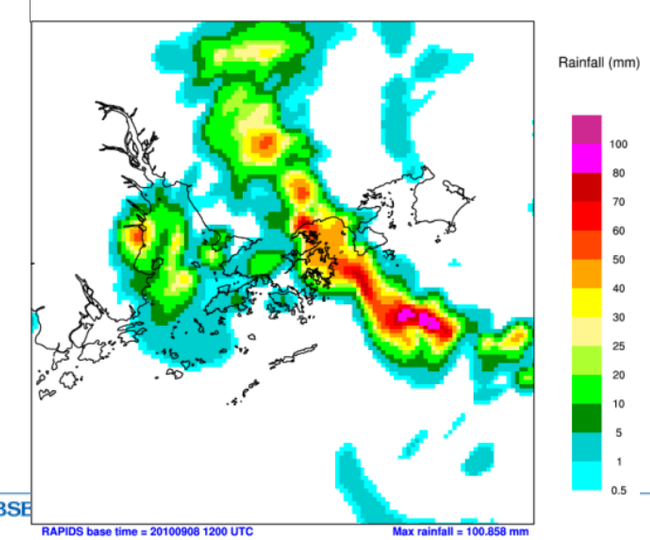
2010-09-09 0100 H
RAPIDS2k T+5h 1-hour accumulated rainfall

Blending

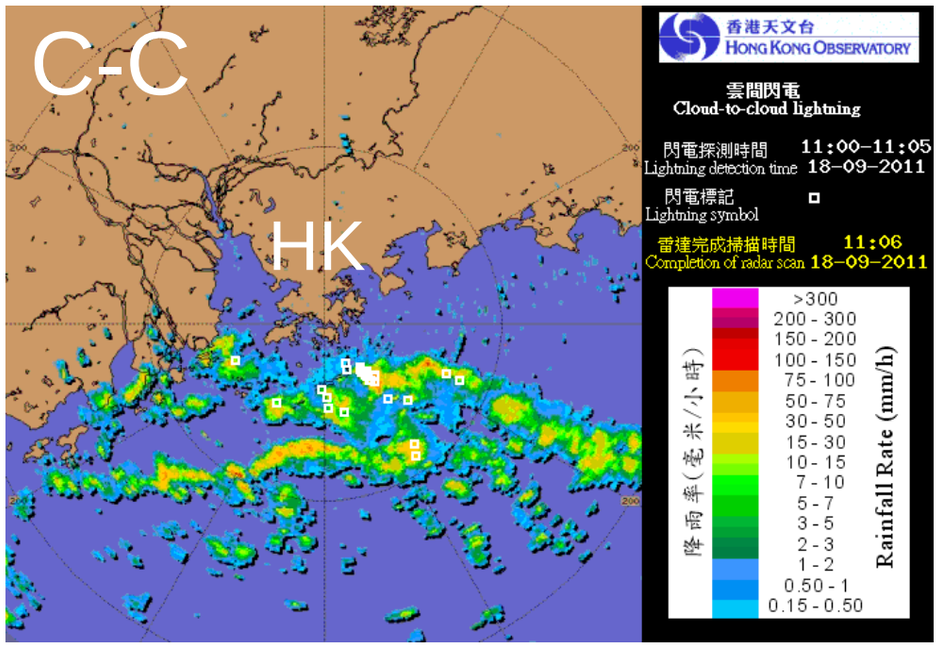
SWIRLS
+
NWP

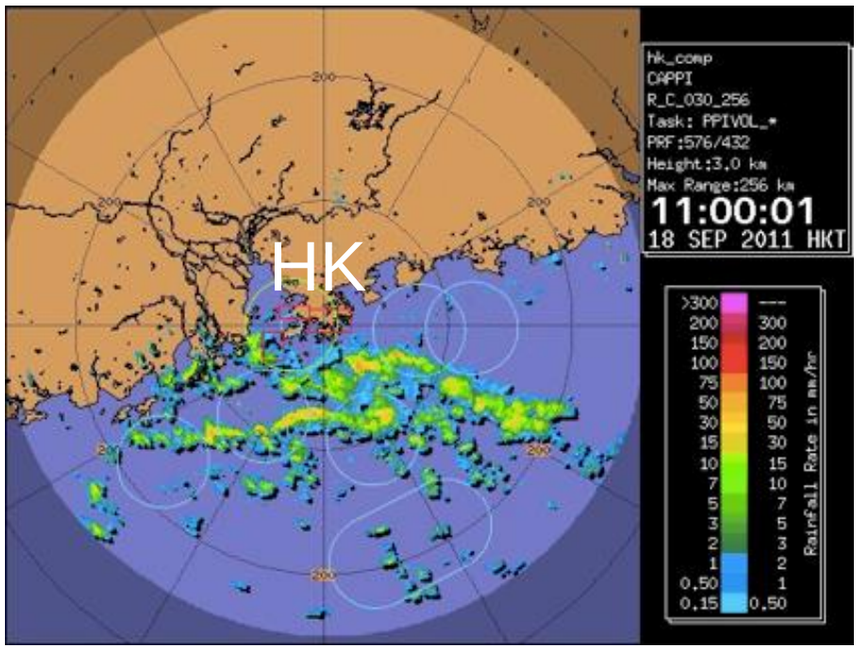




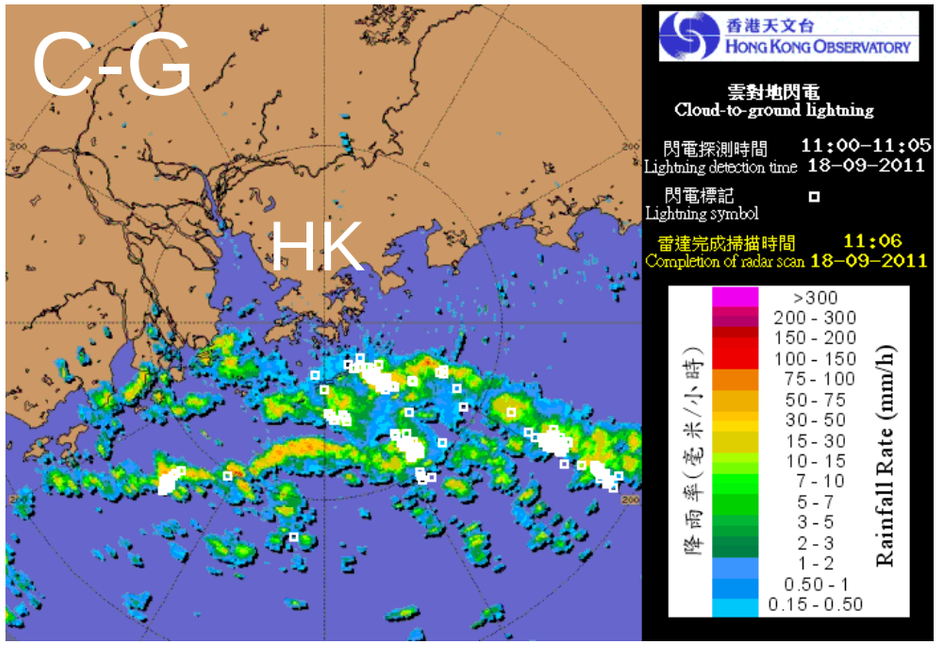


Airport Lightning and Thunderstorm Nowcast

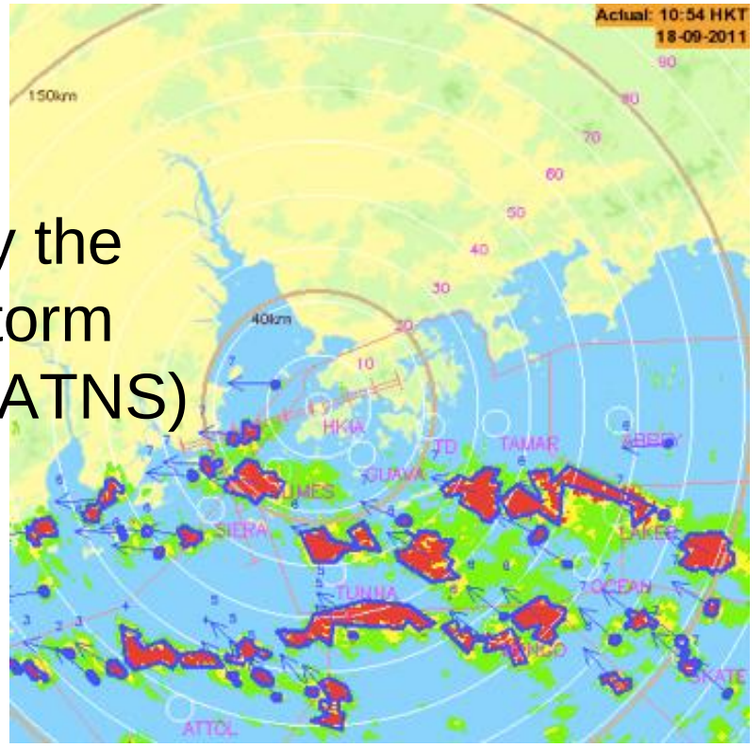




flight diversions due to air traffic blockage from S/SW



Alerts generated by the Aviation Thunderstorm Nowcasting System (ATNS)

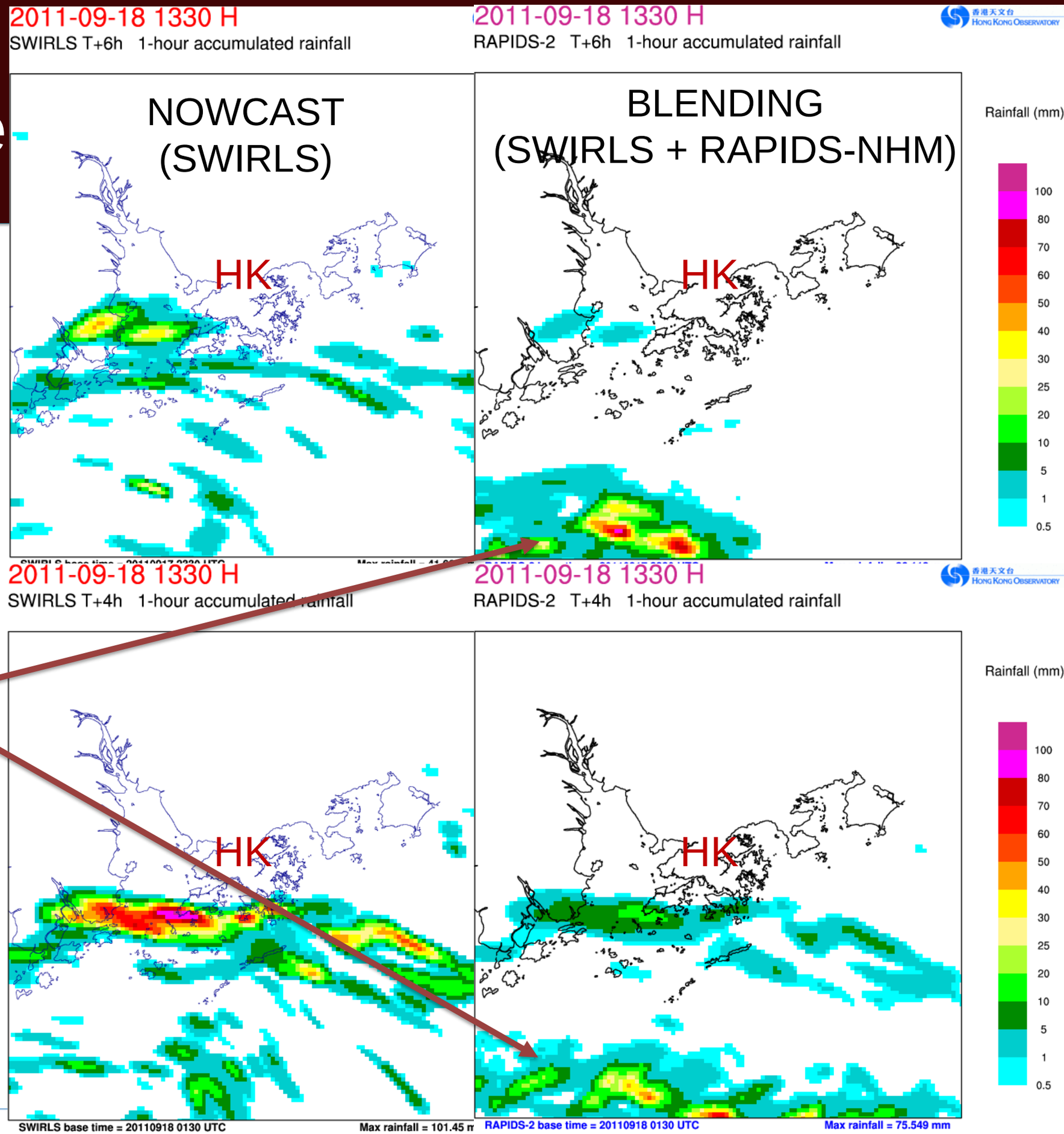


In 3-6 h regime

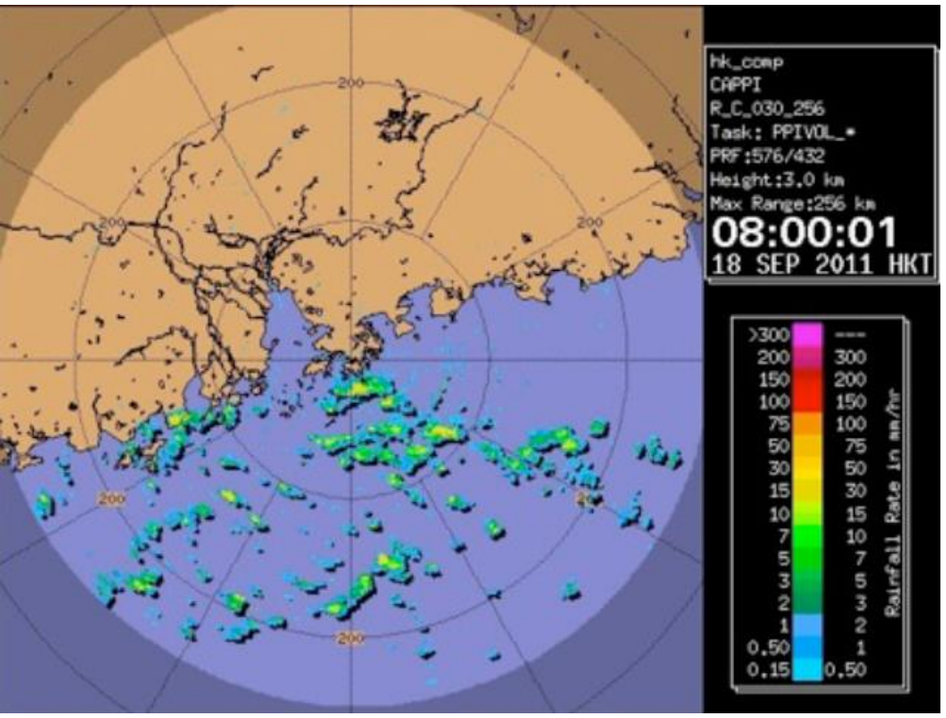
6h forecast from 07:30 HKT

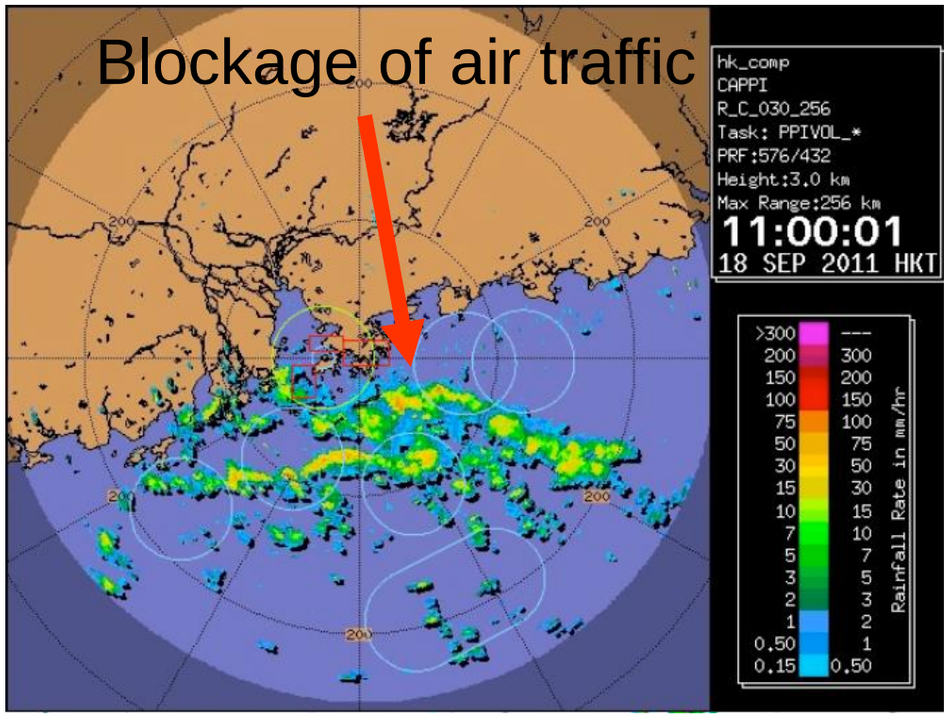
Model suggesting prolonged convection development over coastal waters that can be revealed from the blended QPF

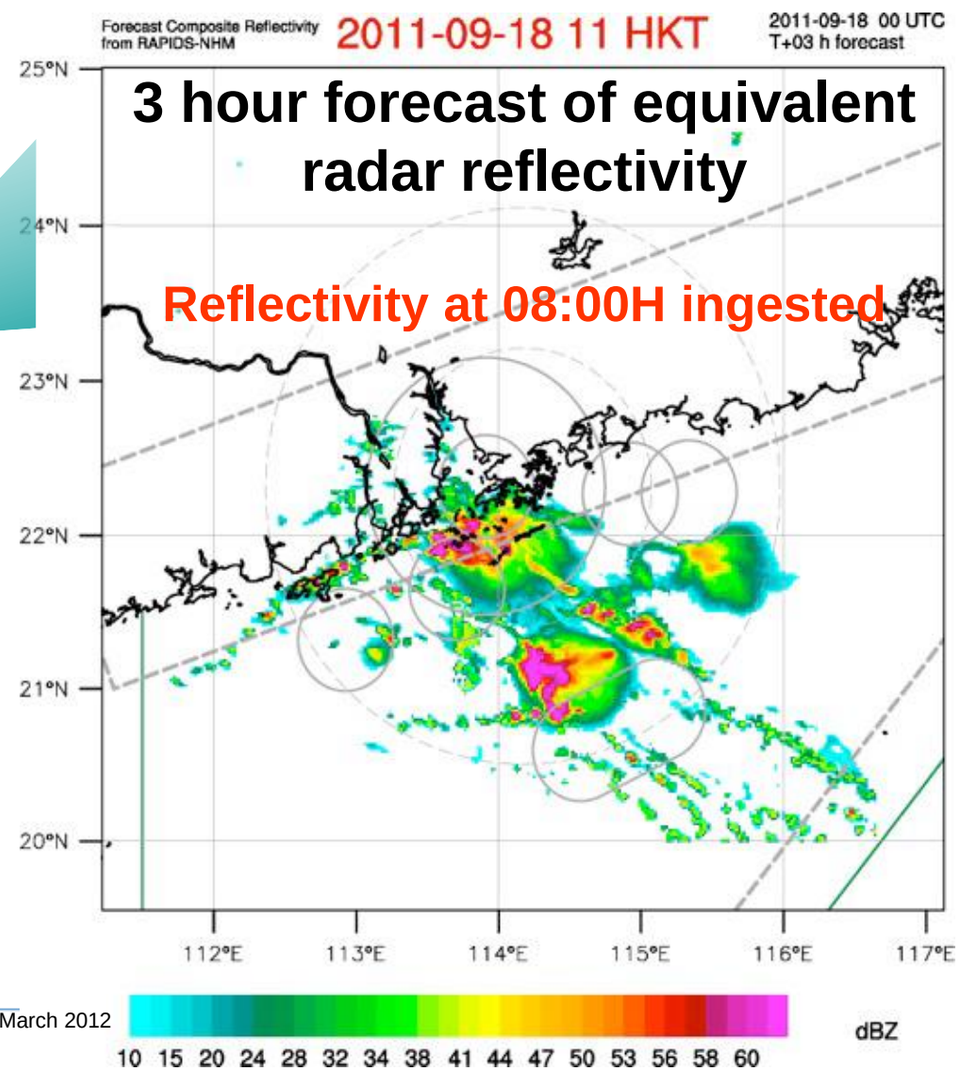
4h forecast from 09:30 HKT

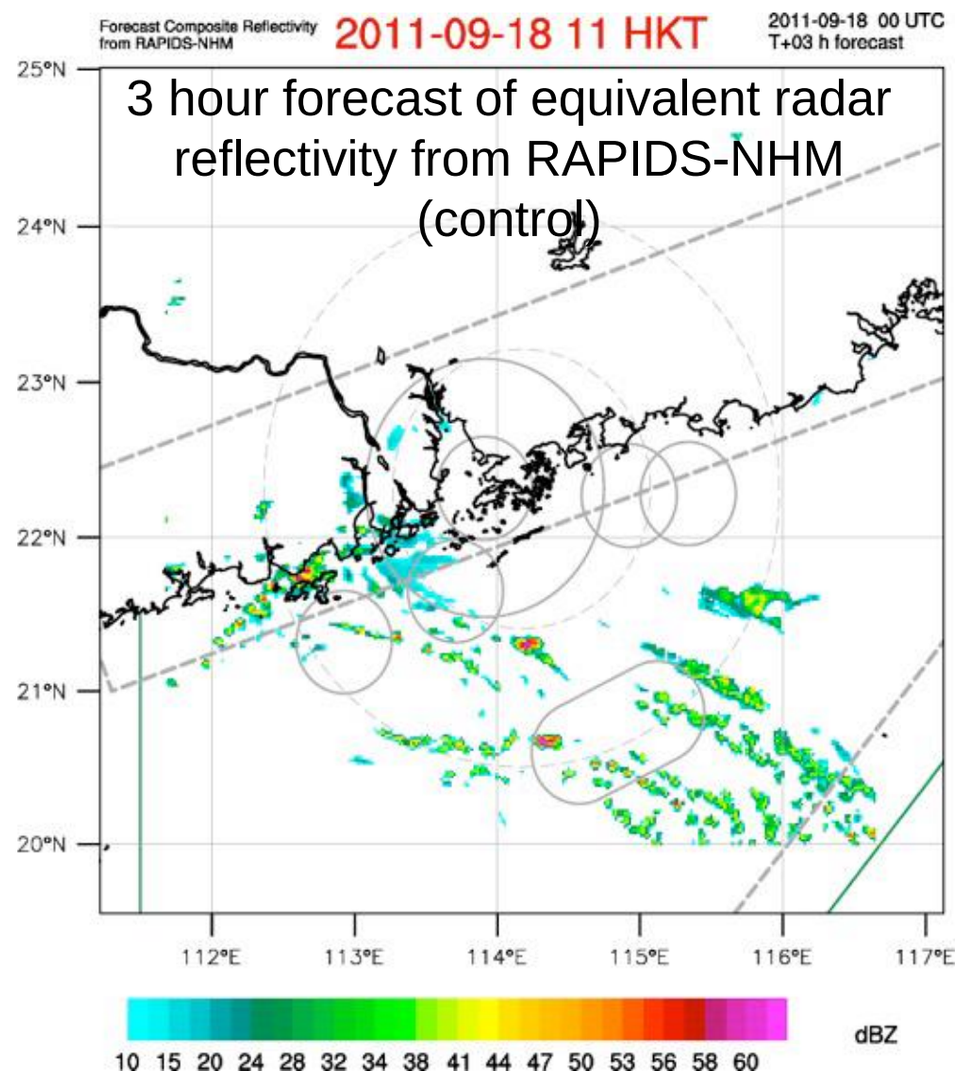


香港天文台
Hong Kong Observatory

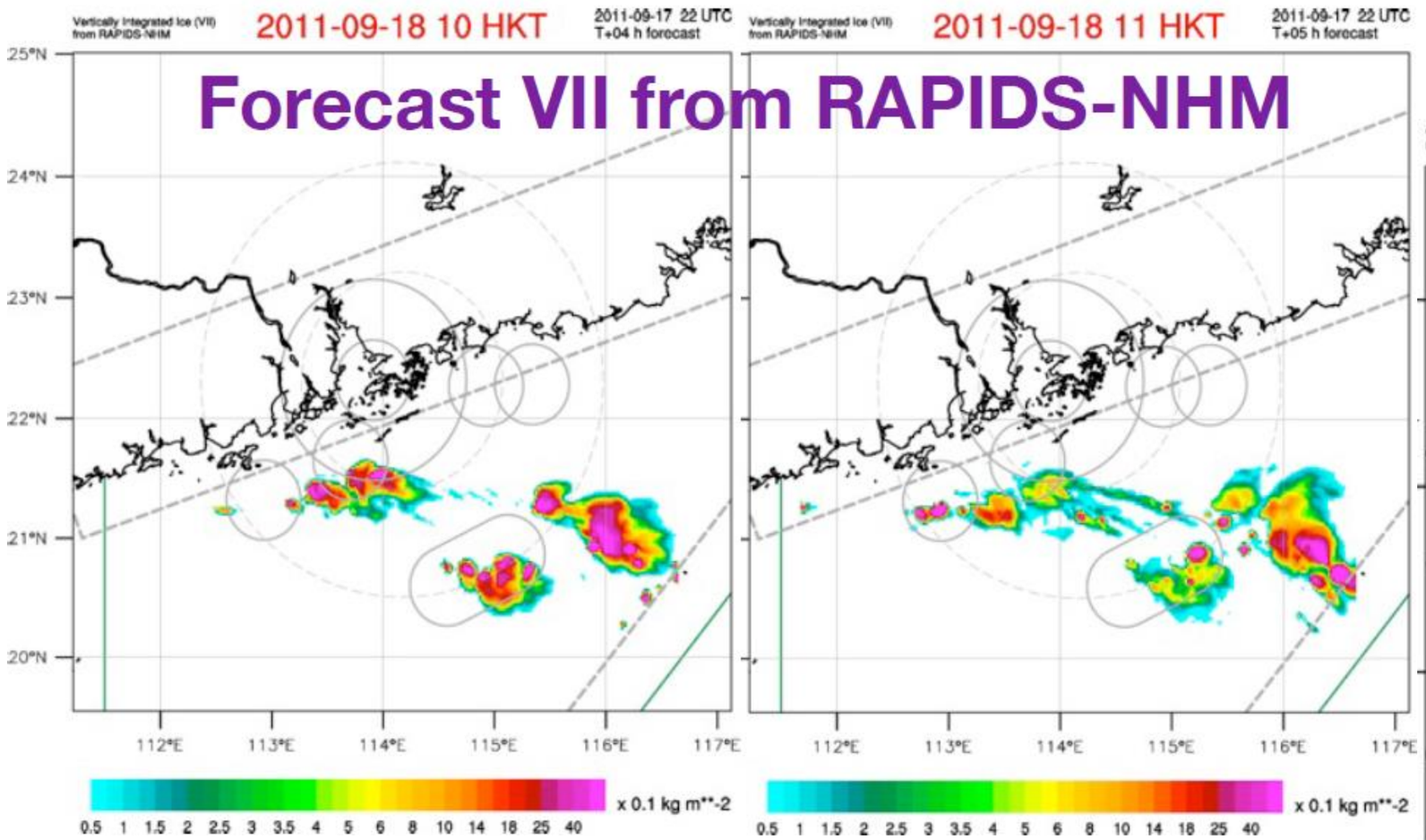

hk_comp
CAPPI
R_C_030_256
Task: PPIVOL_*
PRF:576/432
Height:3.0 km
Max Range:256 km
08:00:01
18 SEP 2011 HKT
Rainfall Rate in mm/hr

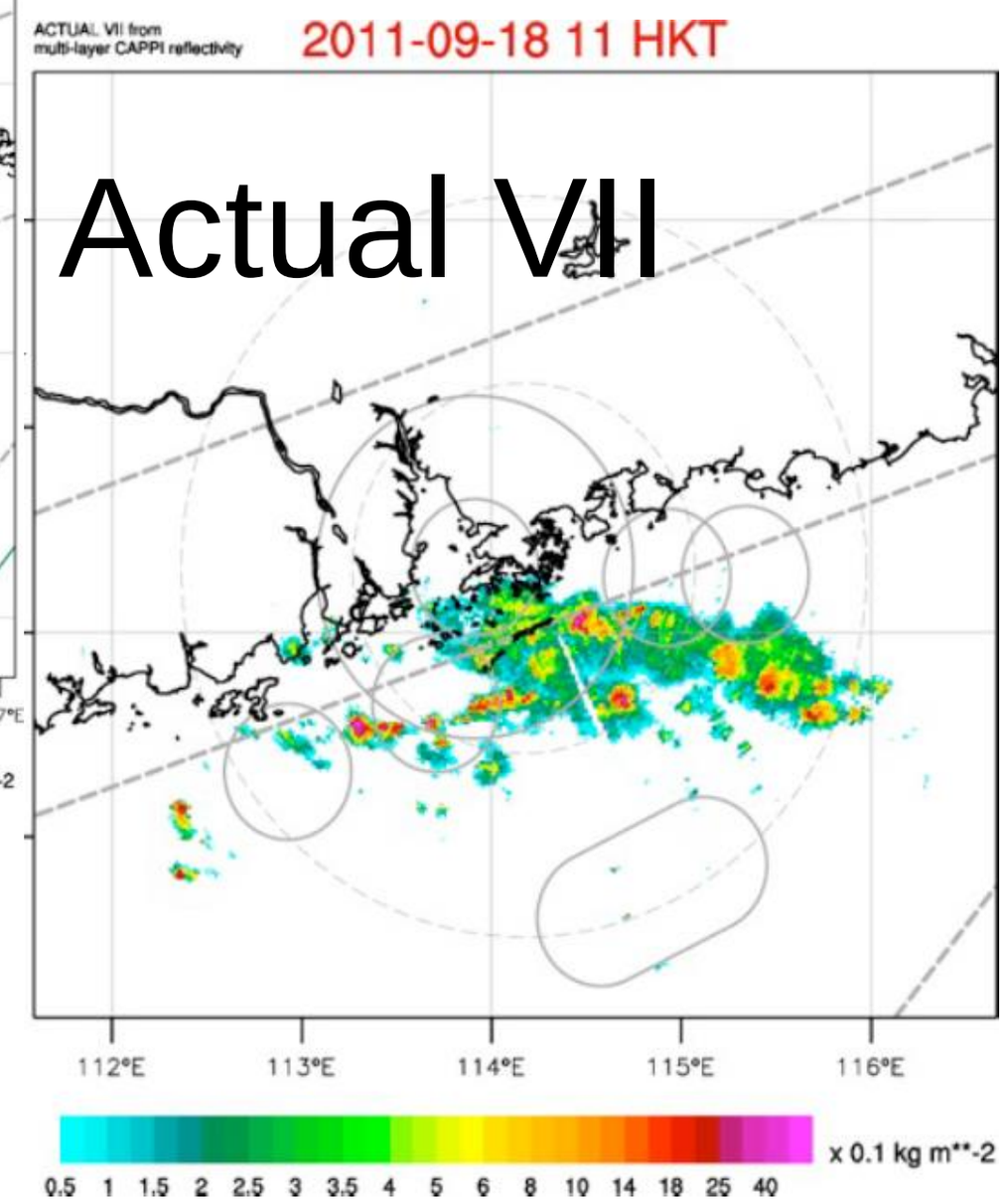

Blockage of air traffic
hk_comp
CAPPI
R_C_030_256
Task: PPIVOL_*
PRF:576/432
Height:3.0 km
Max Range:256 km
11:00:01
18 SEP 2011 HKT
Rainfall Rate in mm/hr


Forecast Composite Reflectivity from RAPIDS-NHM
2011-09-18 11 HKT
2011-09-18 00 UTC
T+03 h forecast
3 hour forecast of equivalent radar reflectivity
Reflectivity at 08:00H ingested
25°N
24°N
23°N
22°N
21°N
20°N
112°E
113°E
114°E
115°E
116°E
117°E
10 15 20 24 28 32 34 38 41 44 47 50 53 56 58 60
dBZ


Forecast Composite Reflectivity from RAPIDS-NHM
2011-09-18 11 HKT
2011-09-18 00 UTC
T+03 h forecast
3 hour forecast of equivalent radar reflectivity from RAPIDS-NHM (control)
25°N
24°N
23°N
22°N
21°N
20°N
112°E
113°E
114°E
115°E
116°E
117°E
10 15 20 24 28 32 34 38 41 44 47 50 53 56 58 60
dBZ

Vertically Integrated Ice $$VII = 1000\pi\rho_i N_o^{3/7}\left(\frac{5.28*10^{-18}}{720}\right)^{4/7}\int_{H_{-10}}^{H_{-40}} Z^{4/7}dH$$

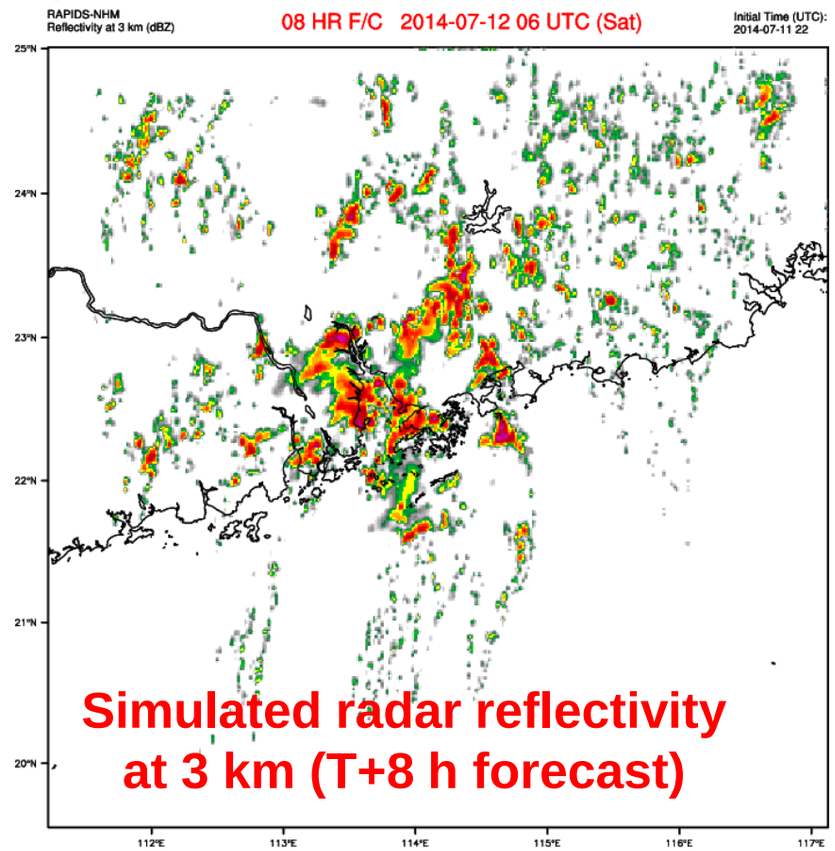


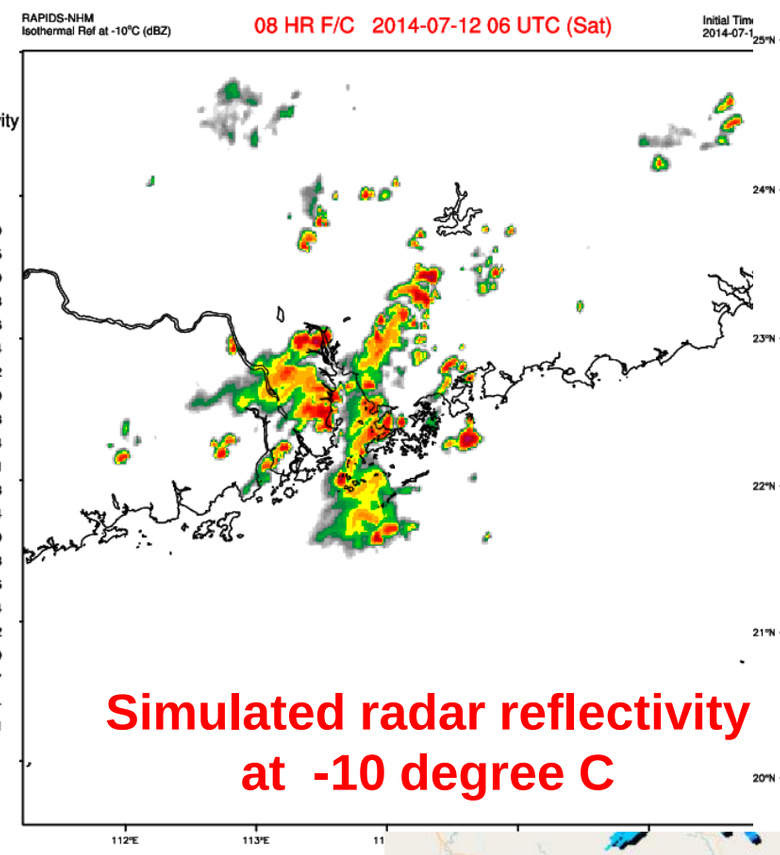


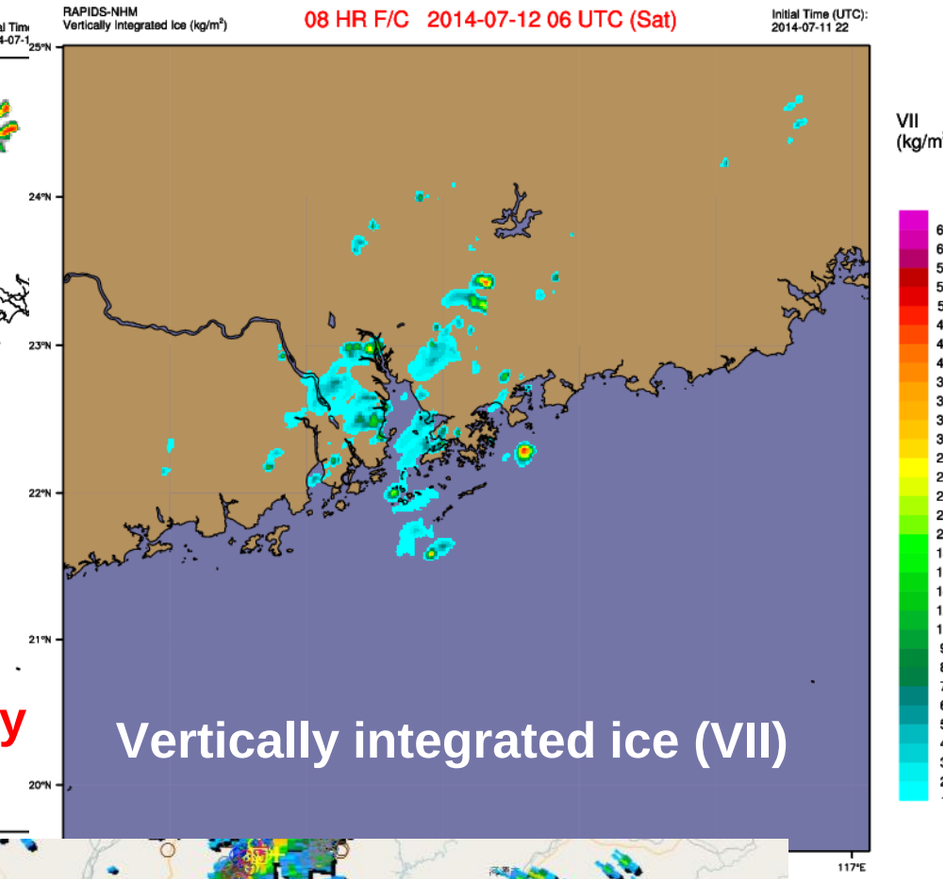
Heights of isotherms from RAPIDS-NHM analysis or forecast

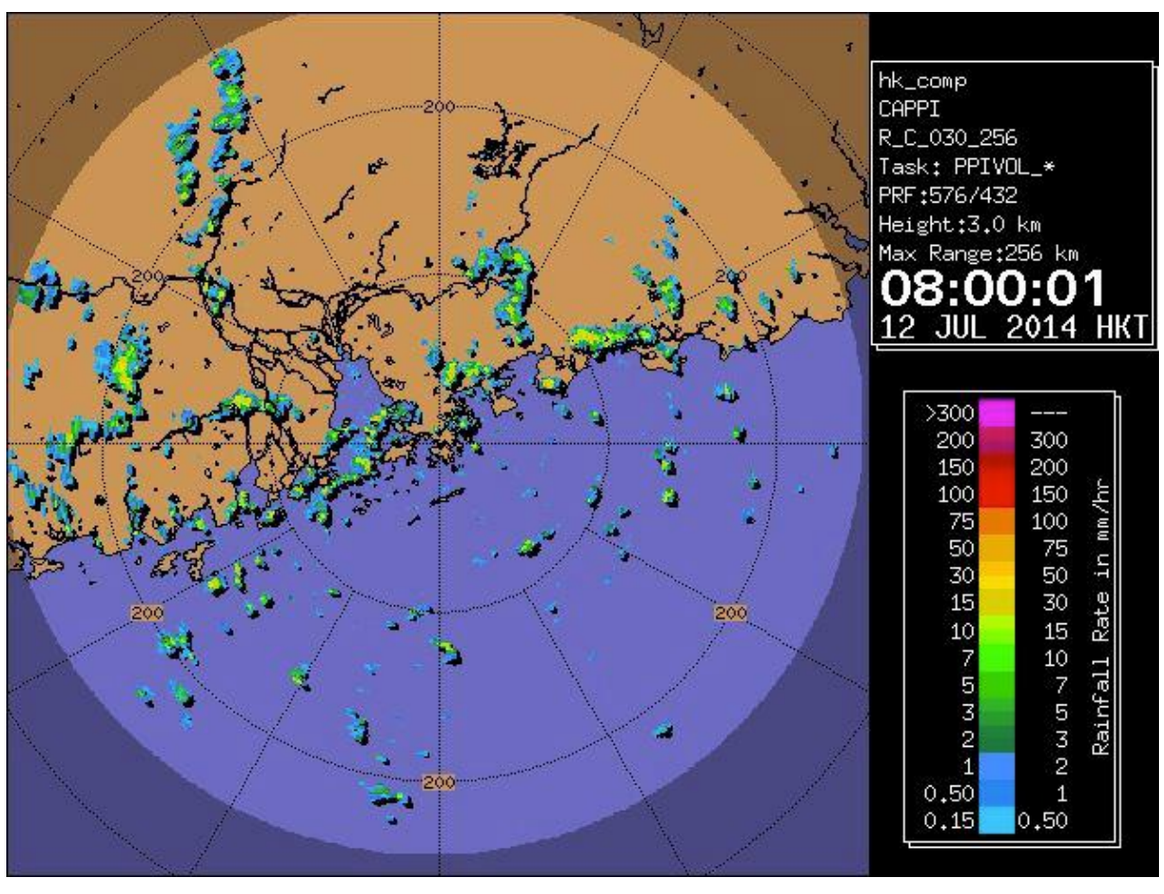
$$\boxed{VII = 1000\pi\rho_i N_o^{3/7}\left(\frac{5.28*10^{-18}}{720}\right)^{4/7}\int_{H_{-10}}^{H_{-40}} Z^{4/7}dH}$$

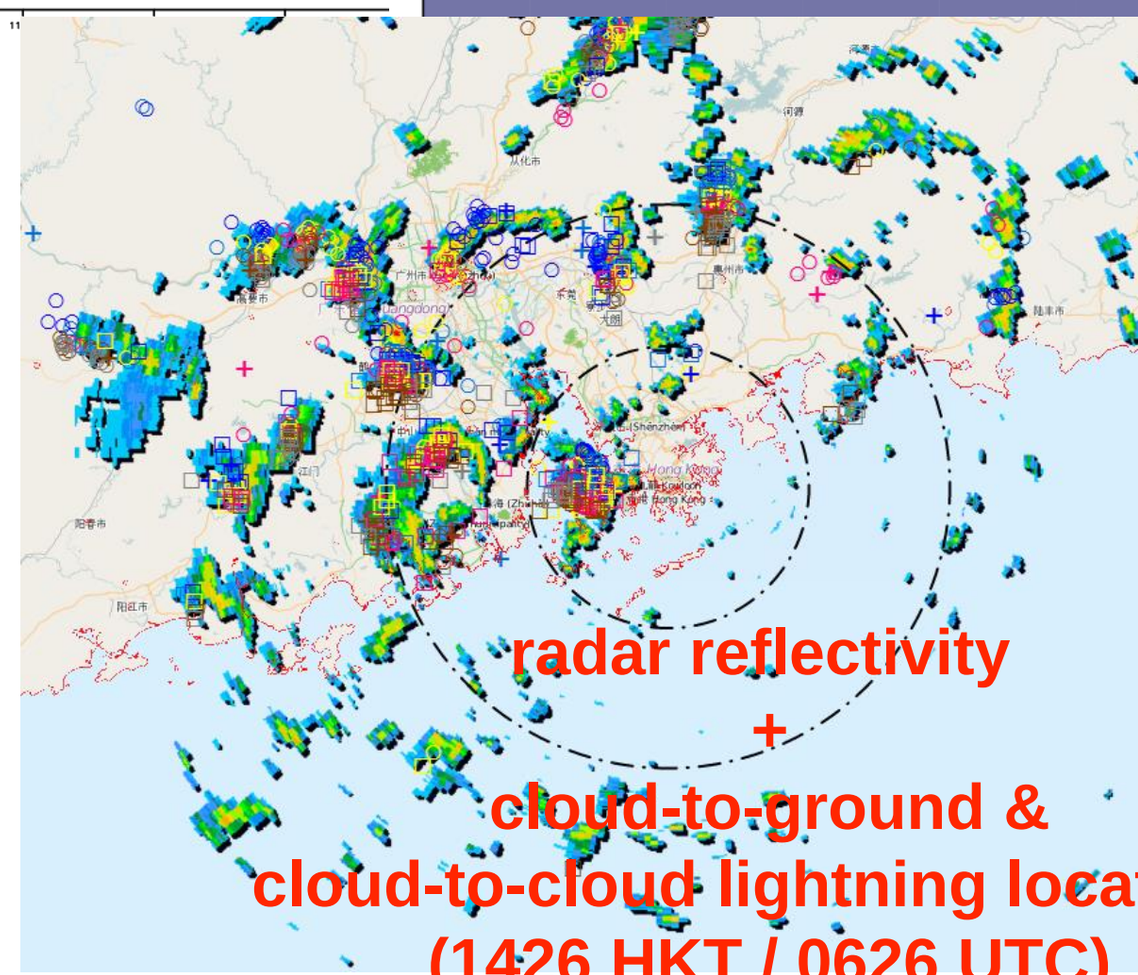
香港天文台
HONG KONG OBSERVATORY











Blending of convective forecast parameter

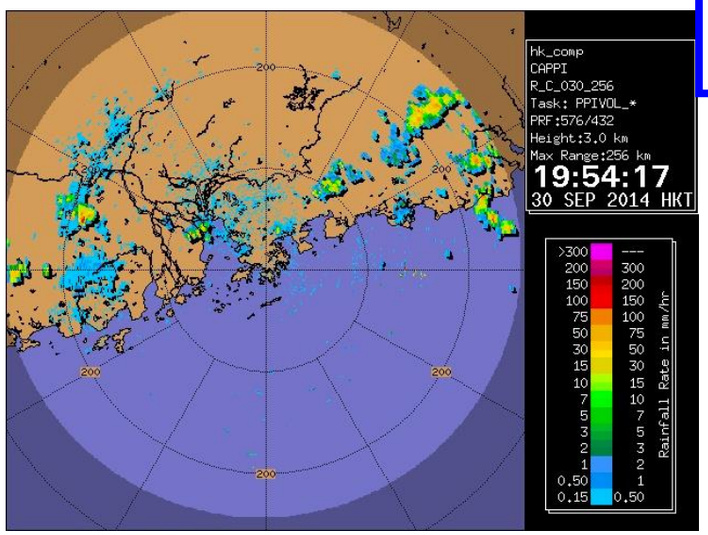
香港天文台
HONG KONG OBSERVATORY

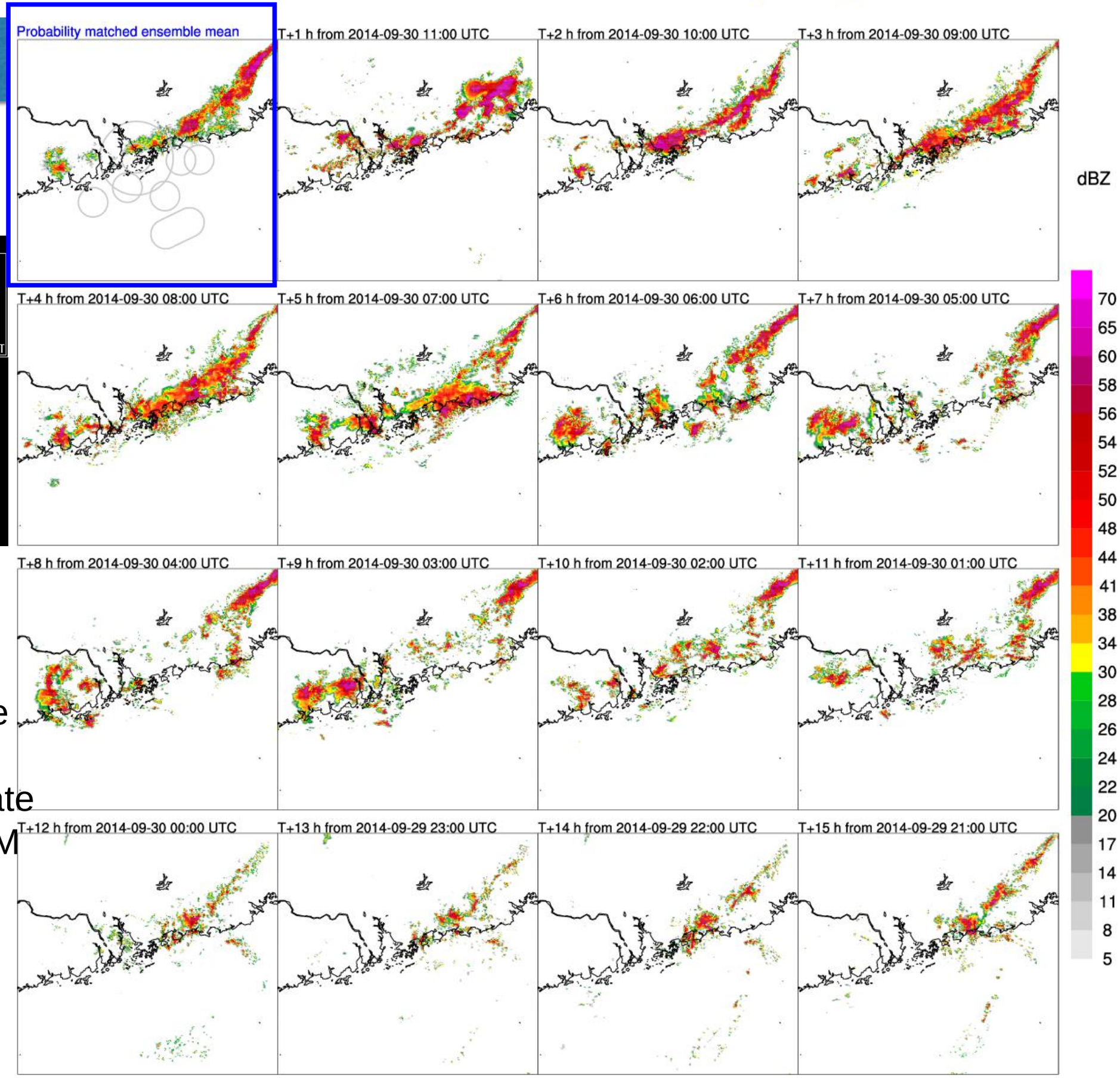
RAPIDS-NHM
Time-lagged ensemble

2014-09-30 12:00 UTC (TUE)

Simulated Reflectivity
at 3 km level

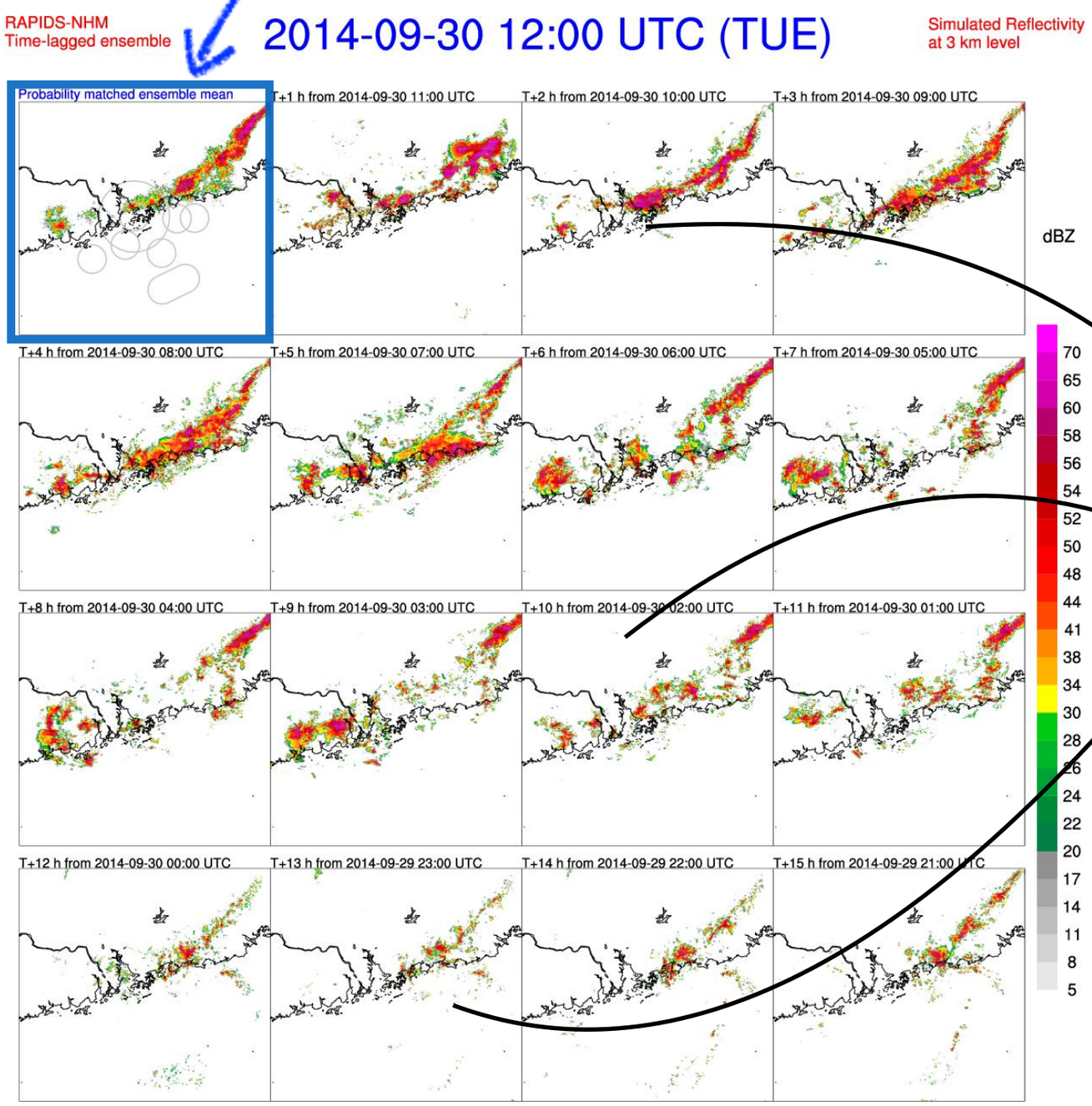
Probability matched ensemble mean





Ensemble of "possible scenarios" from successive hourly-update cycles of RAPIDS-NHM

Probability matched ensemble mean



map the value in G(k) onto location in E(i,j)

rank gridded reflectivity forecasts from N TLE members in descending order;

select every N-th value starting from N/2-th value

→

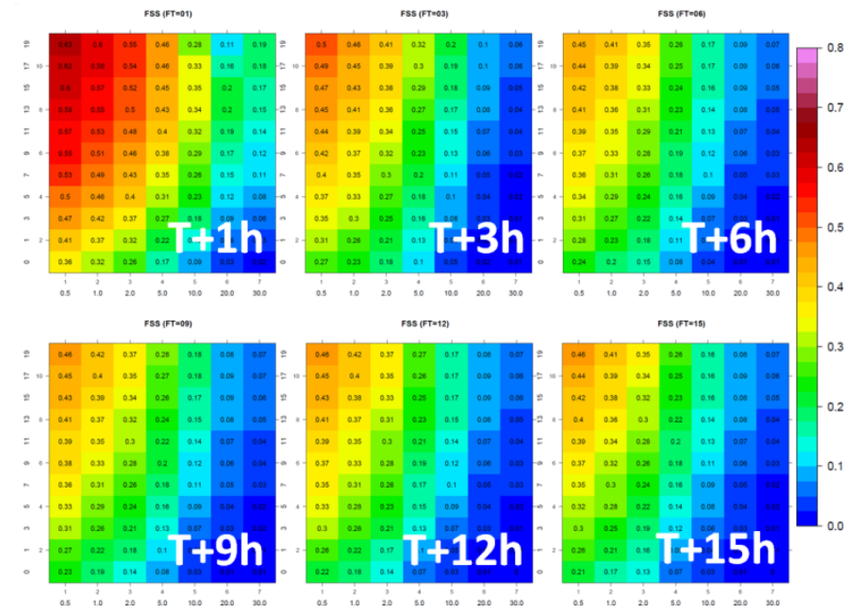
G(k=1…NX*NY)

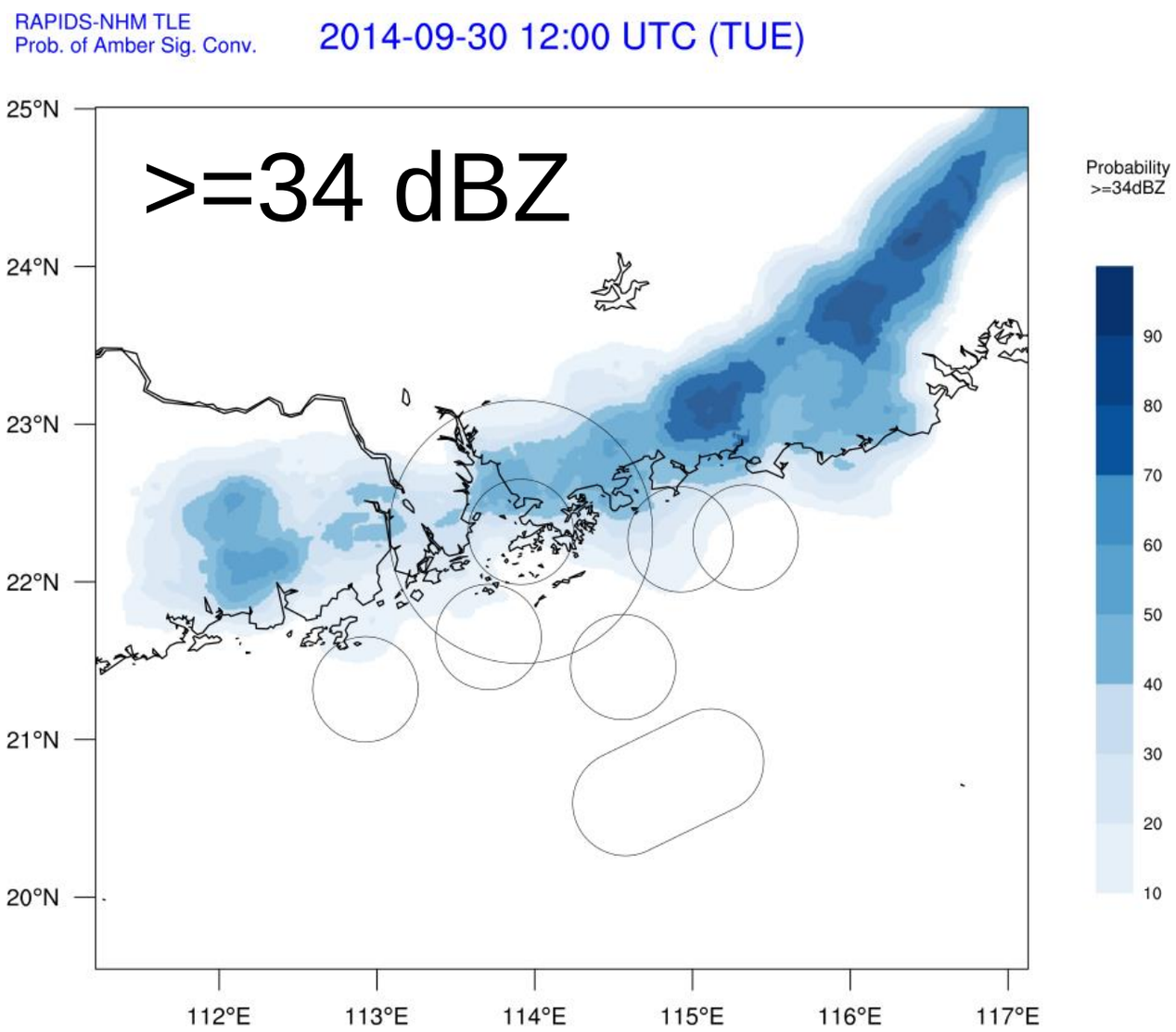
compute ensemble mean E(i,j), sort the gridded reflectivity from the largest to smallest values

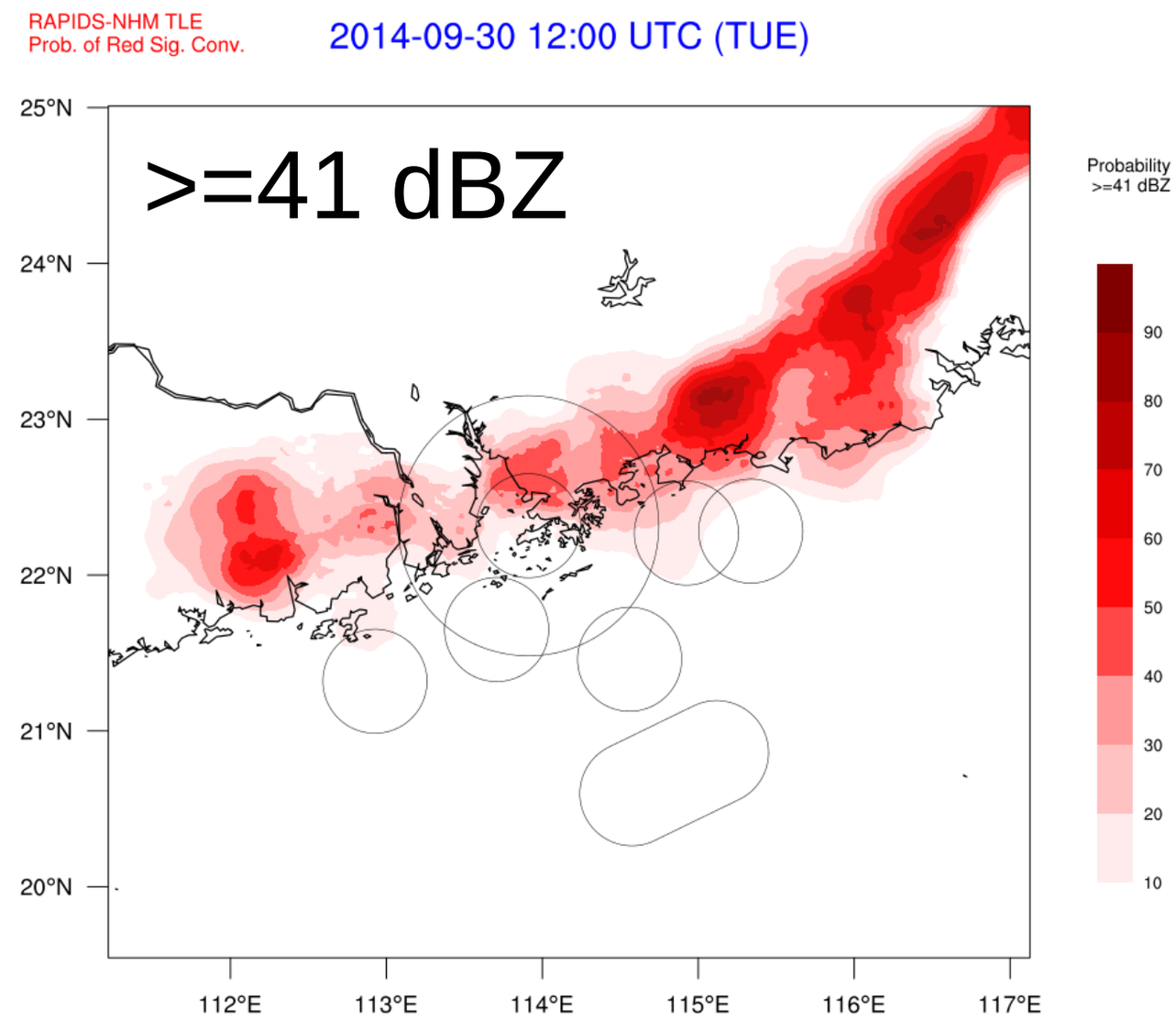
intensity

pattern

- Using spatial-intensity scale dependent verification score (FSS) at different lead times, consider the likelihood of significant convection levels (34 & 41 dBZ) by counting fraction of "storm grids" within a box with size determined by a prescribed FSS from <u>all available</u> time-lagged ensemble members





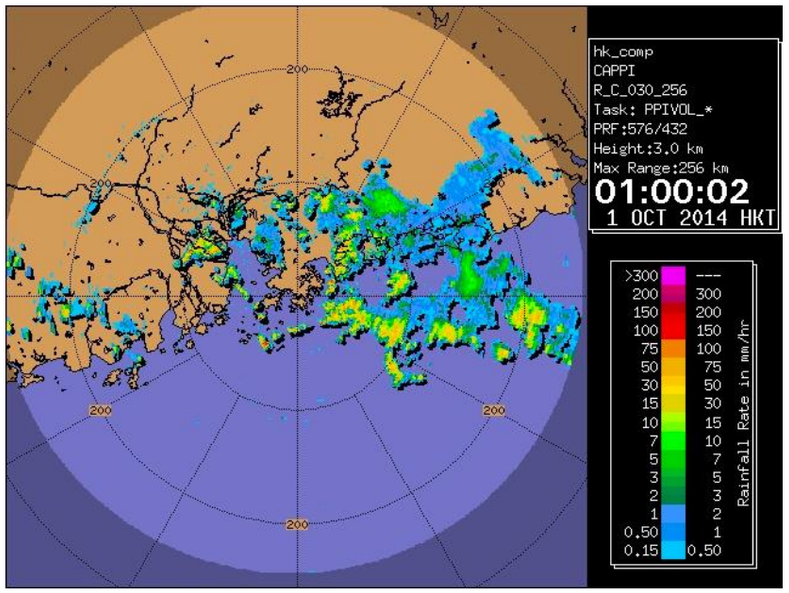


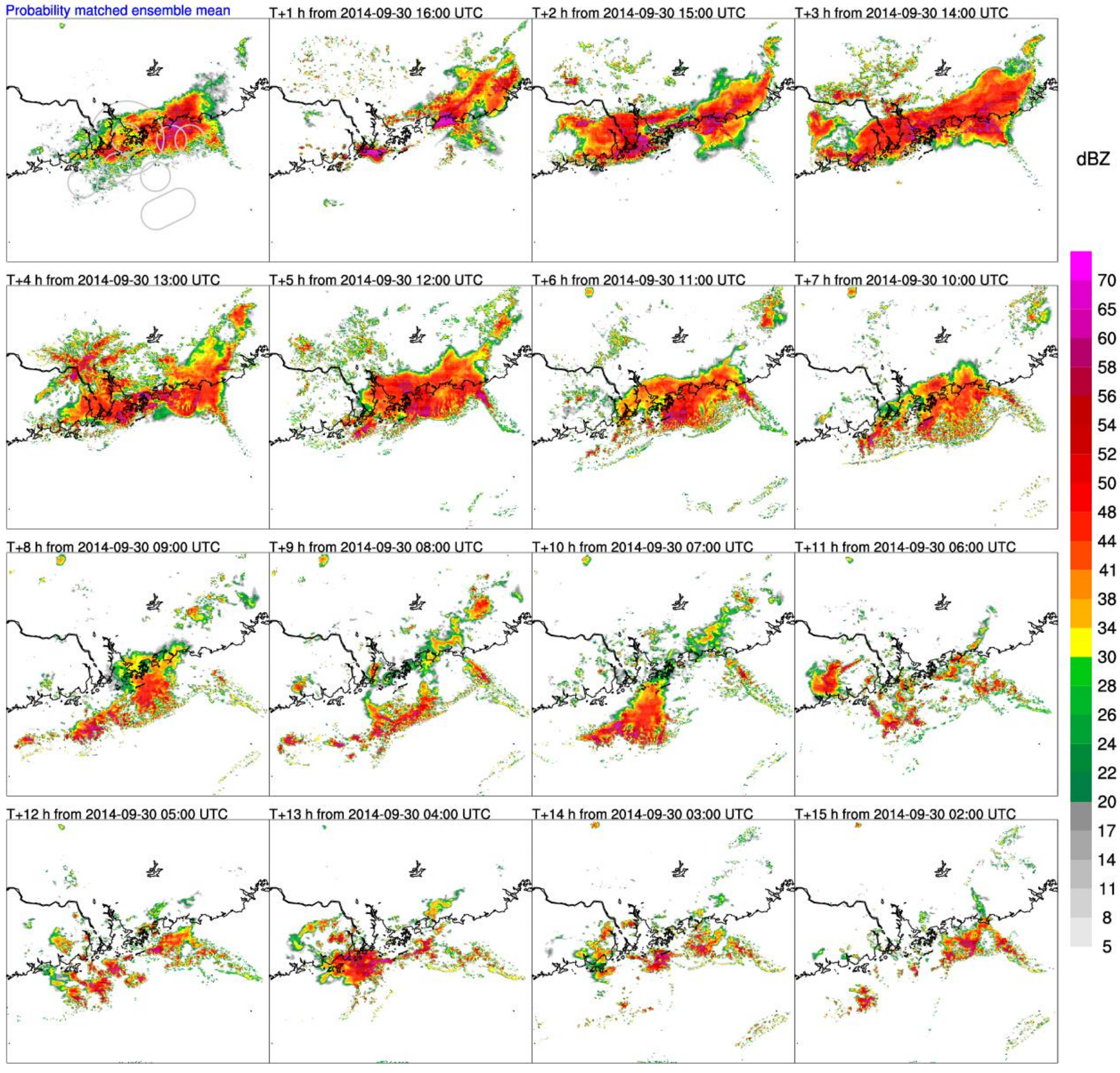
香港天文台
HONG KONG OBSERVATORY

RAPIDS-NHM
Time-lagged ensemble

2014-09-30 17:00 UTC (TUE)

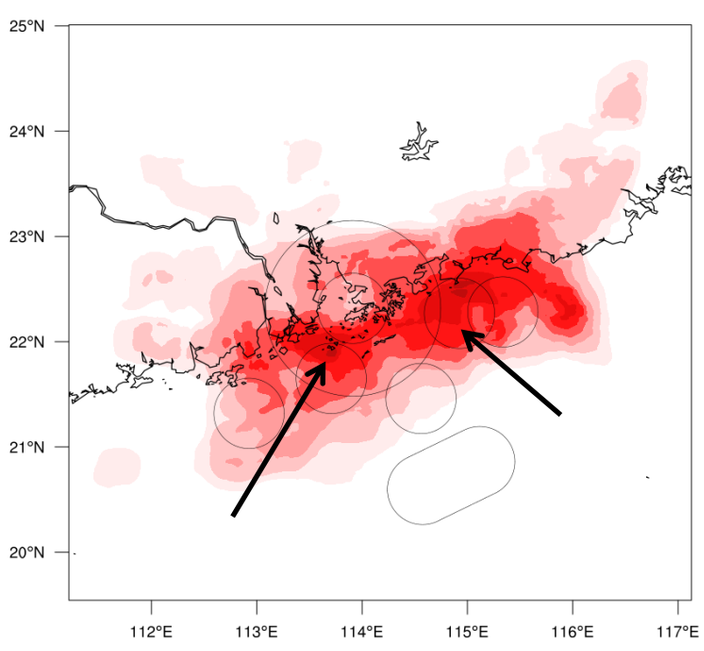
Simulated Reflectivity
at 3 km level



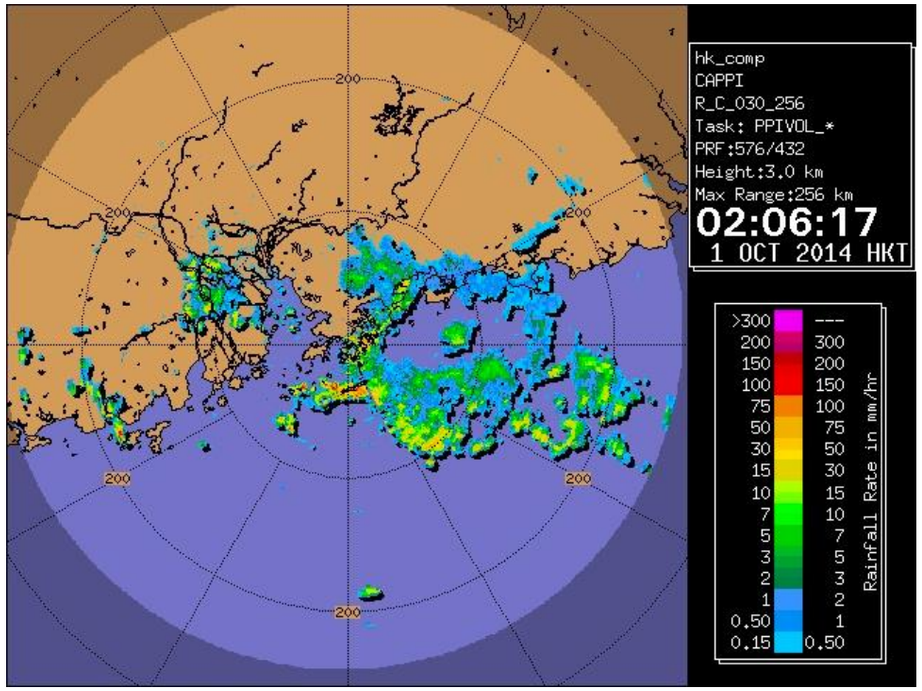


RAPIDS-NHM TLE
Prob. of Red Sig. Conv.

2014-09-30 17:00 UTC (TUE)

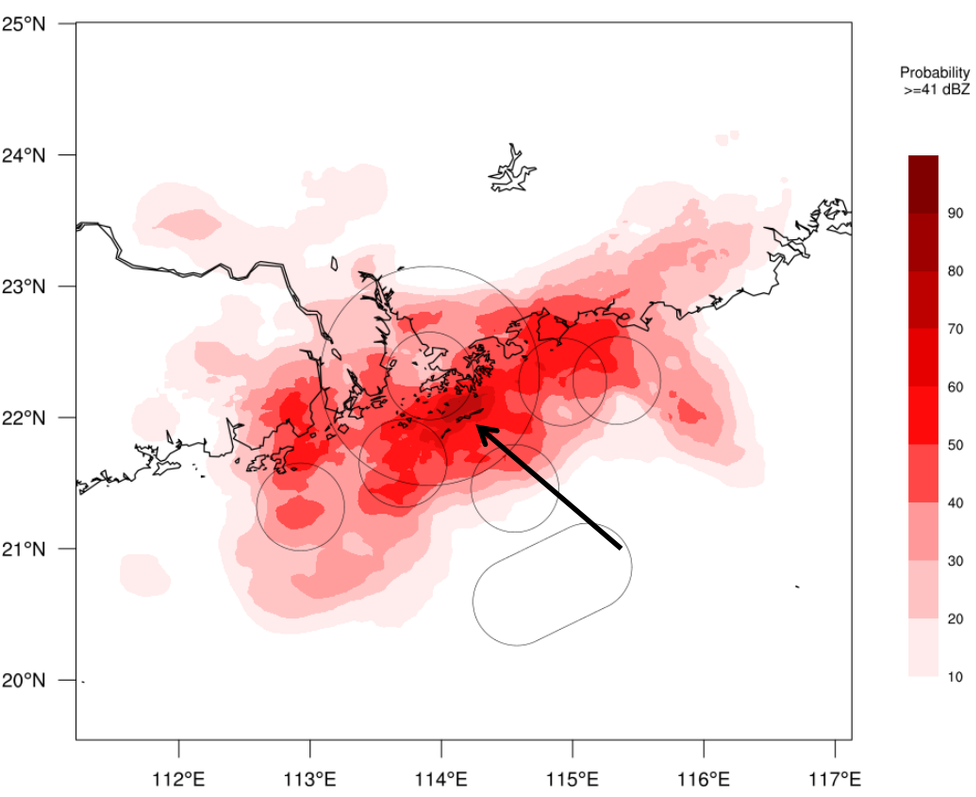


香港天文台
HONG KONG OBSERVATORY



RAPIDS-NHM TLE
Prob. of Red Sig. Conv.

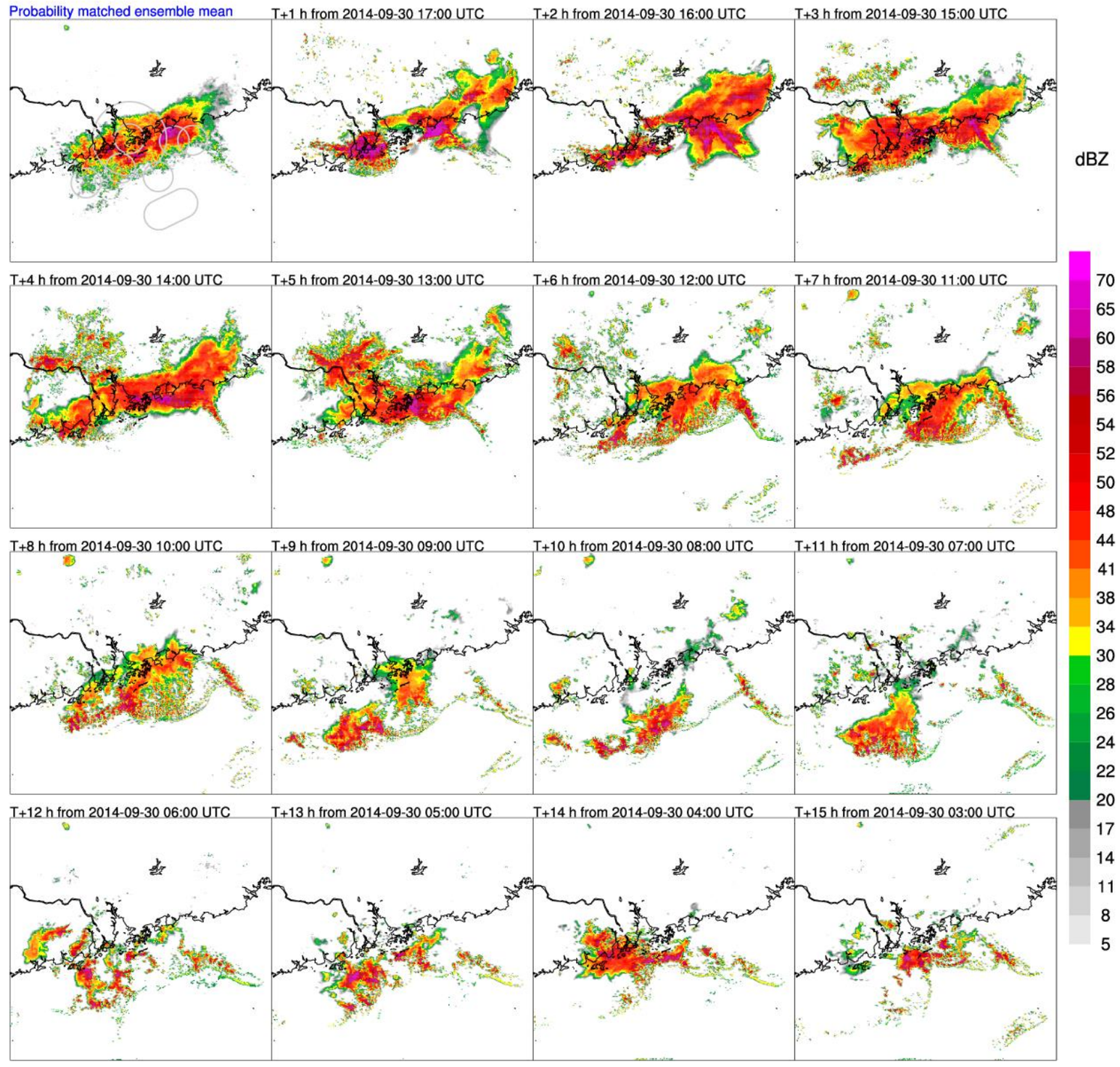
2014-09-30 18:00 UTC (TUE)



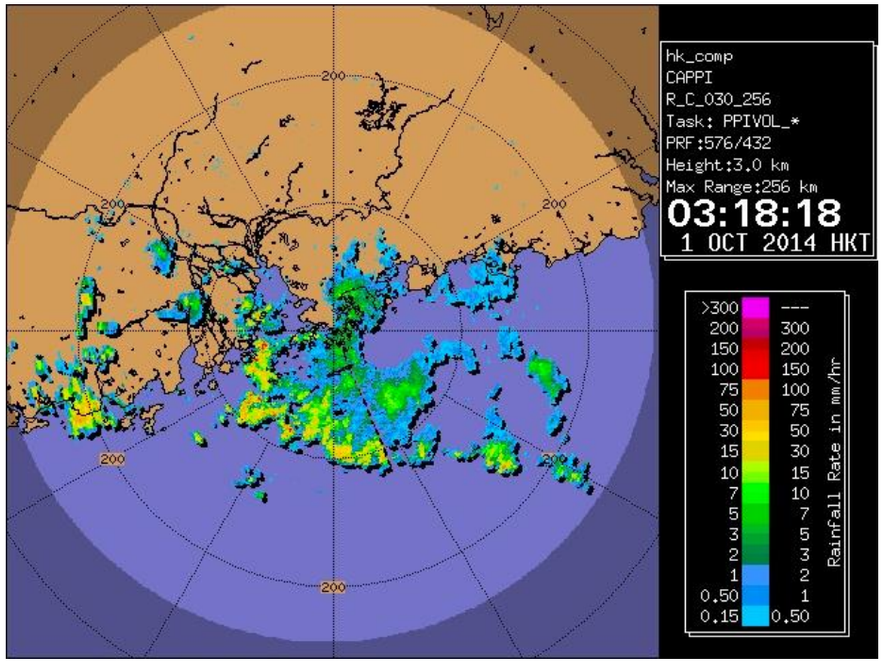
RAPIDS-NHM
Time-lagged ensemble

2014-09-30 18:00 UTC (TUE)

Simulated Reflectivity
at 3 km level

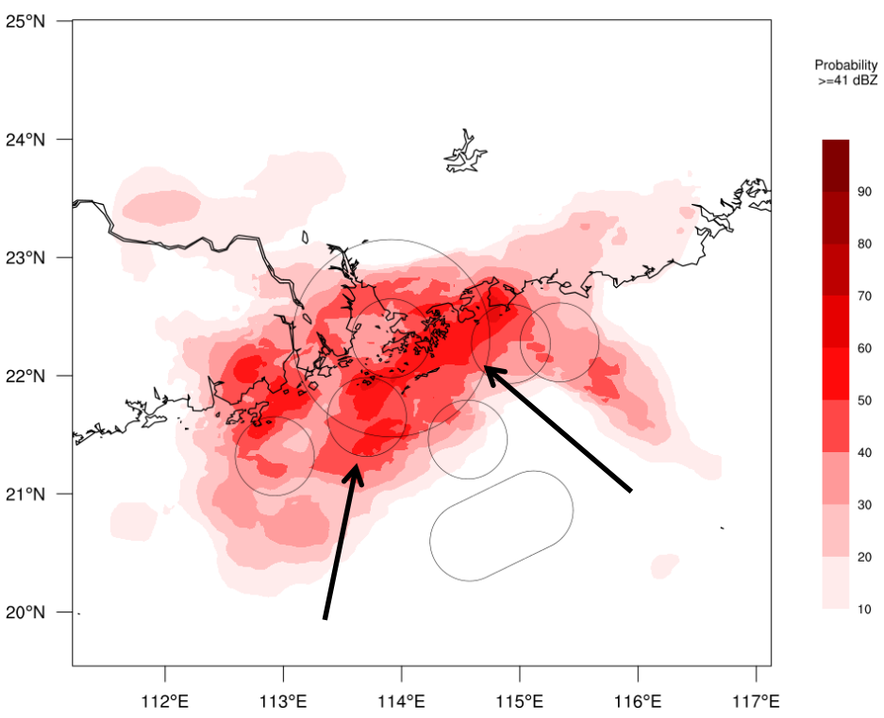


香港天文台
HONG KONG OBSERVATORY



RAPIDS-NHM TLE
Prob. of Red Sig. Conv.

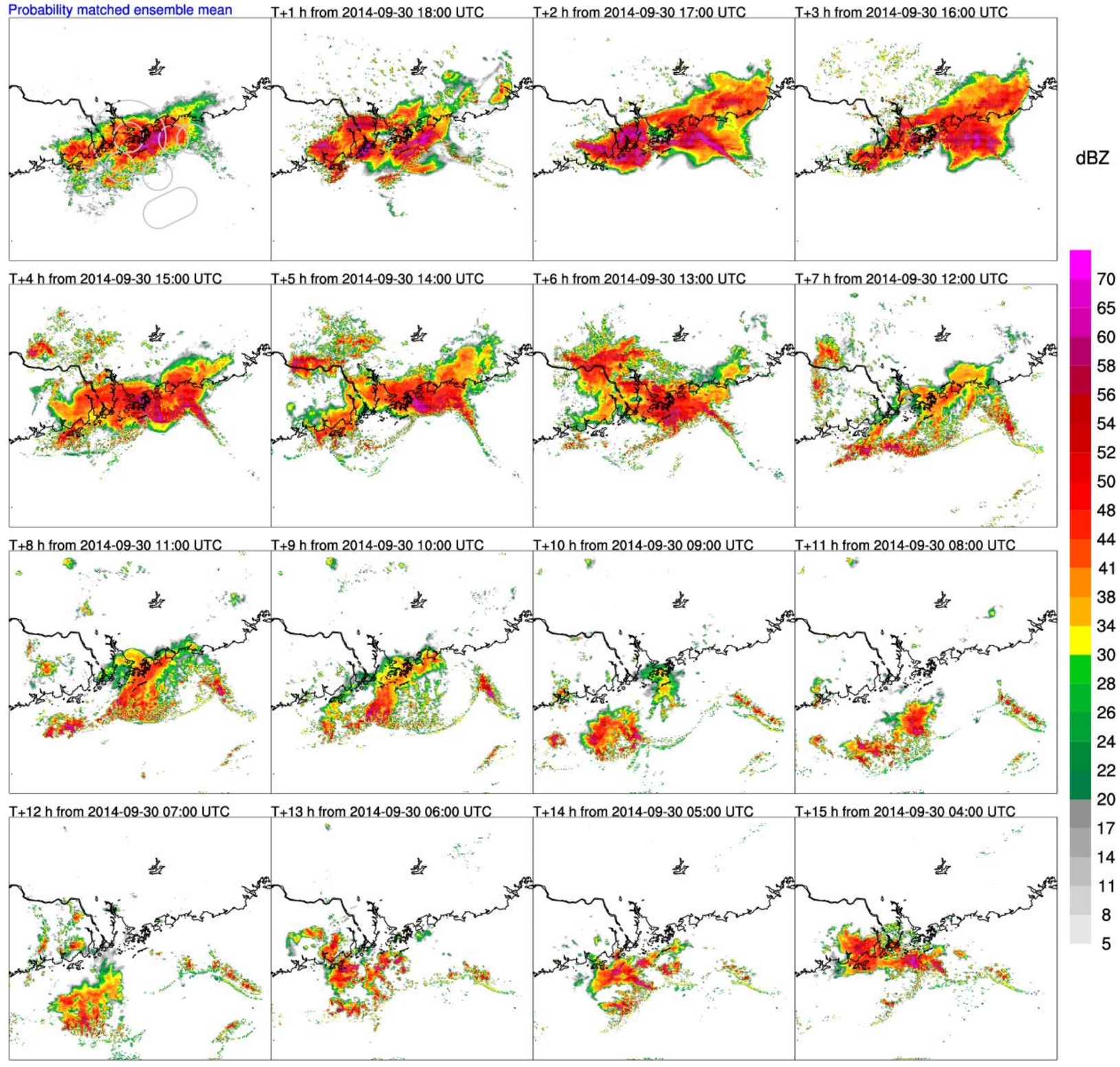
2014-09-30 19:00 UTC (TUE)



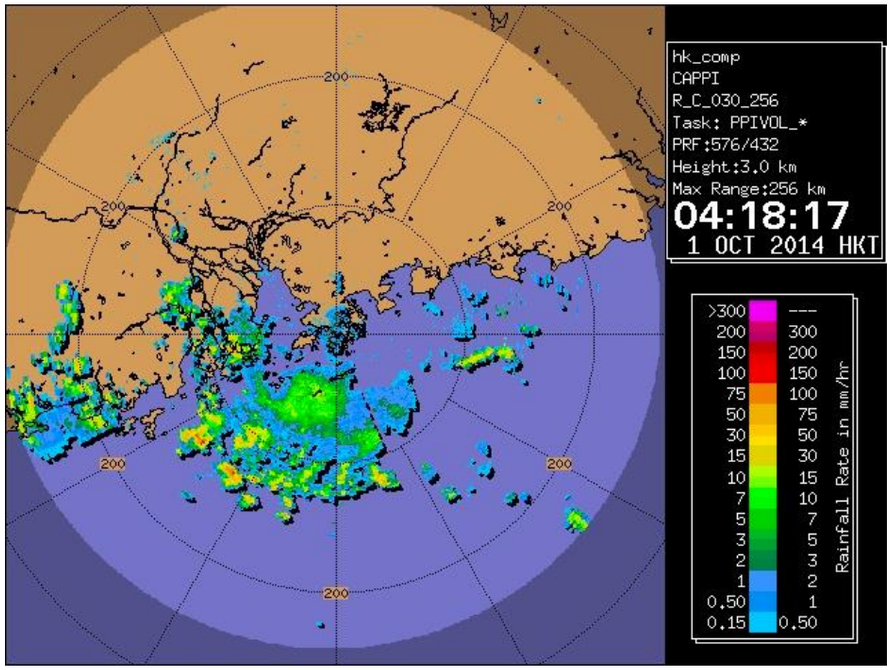
RAPIDS-NHM
Time-lagged ensemble

2014-09-30 19:00 UTC (TUE)

Simulated Reflectivity
at 3 km level



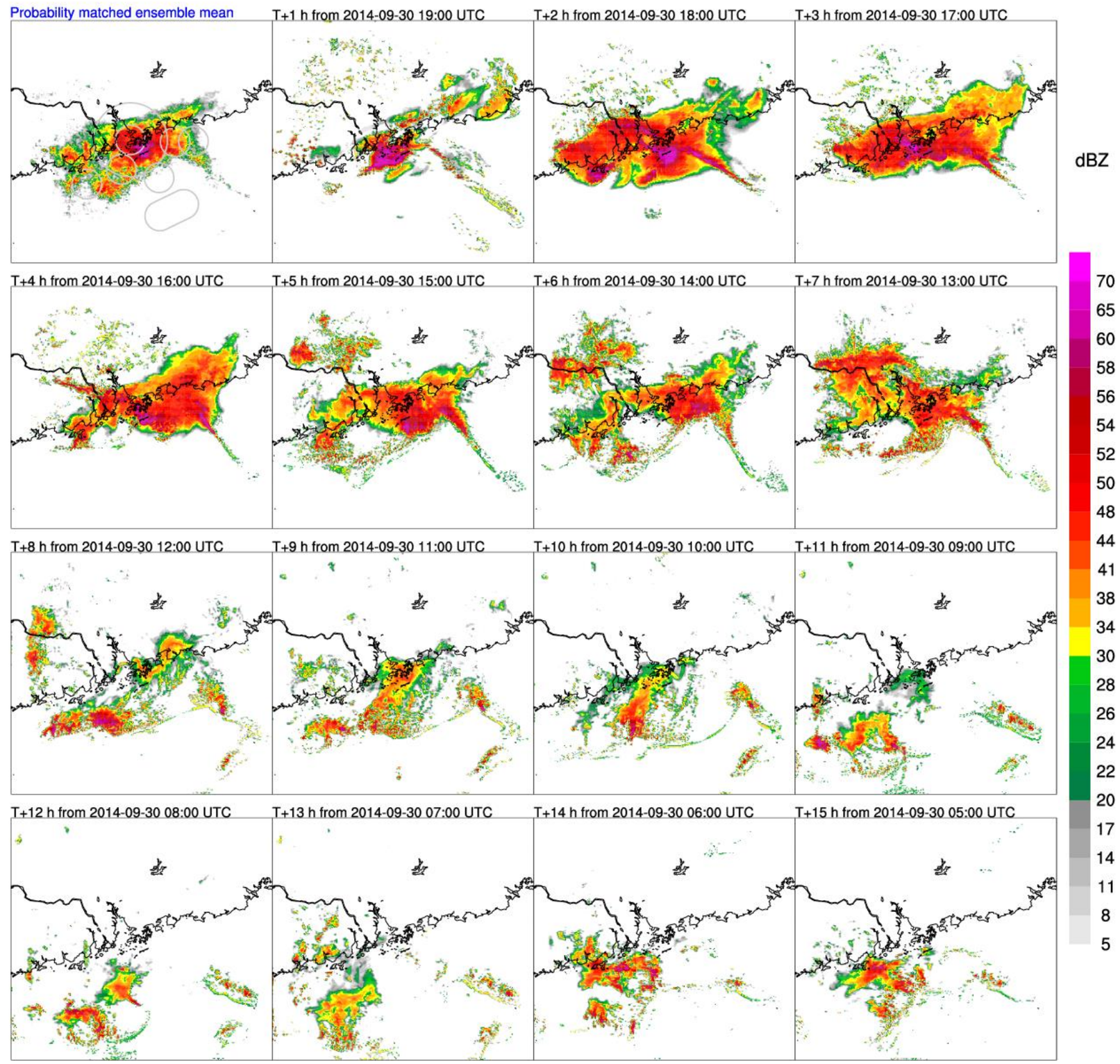
香港天文台
HONG KONG OBSERVATORY



RAPIDS-NHM
Time-lagged ensemble

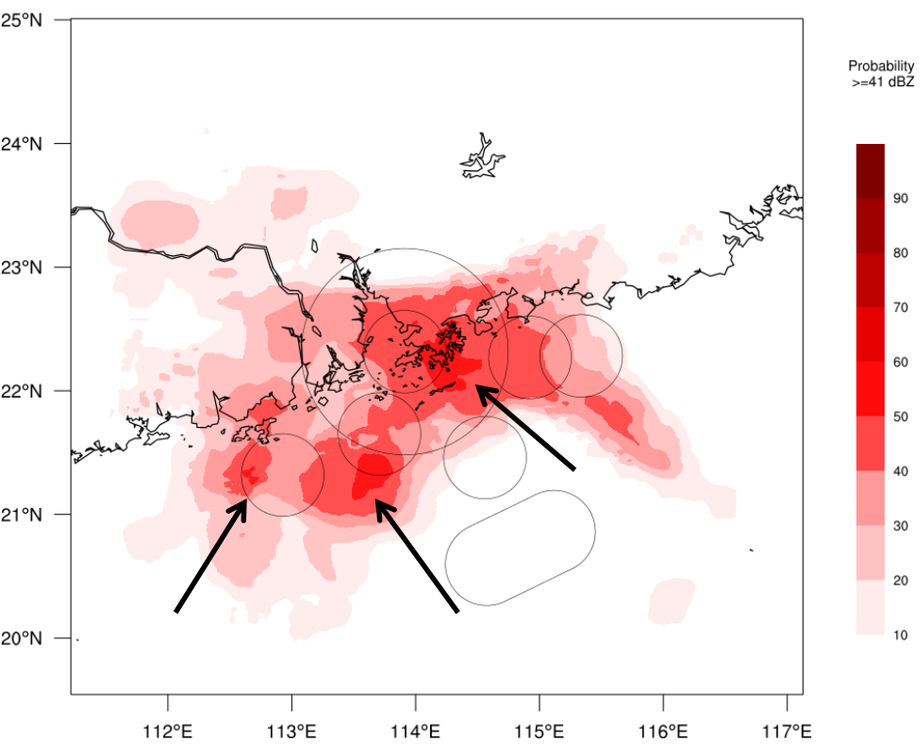
2014-09-30 20:00 UTC (TUE)

Simulated Reflectivity
at 3 km level

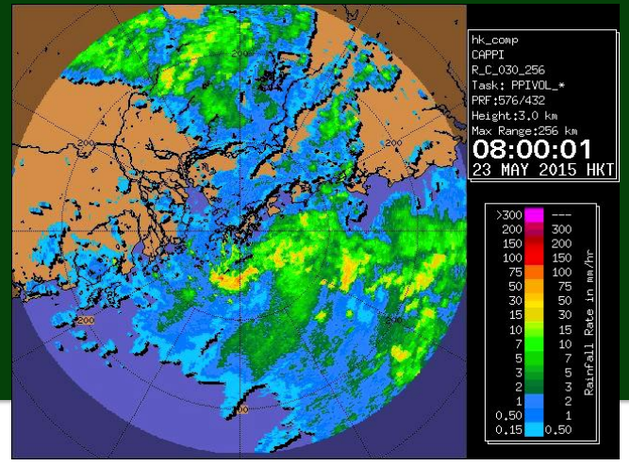


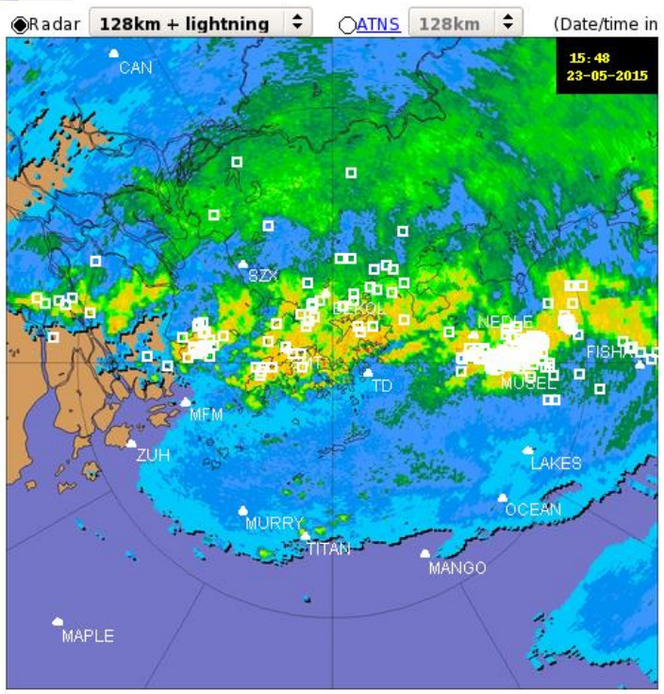
RAPIDS-NHM TLE
Prob. of Red Sig. Conv.

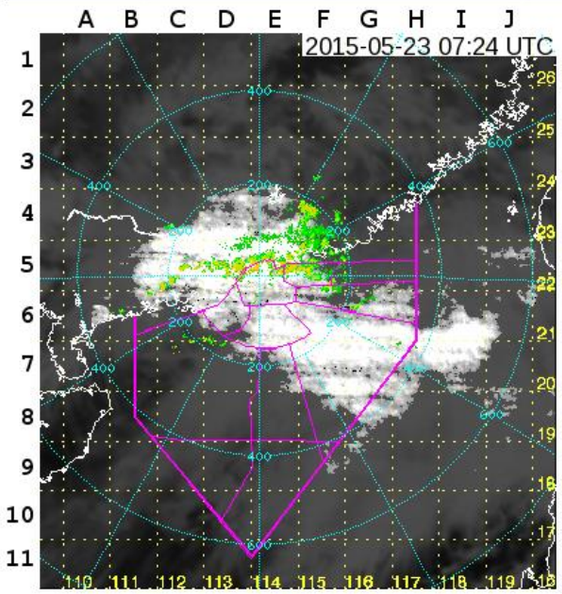
2014-09-30 20:00 UTC (TUE)

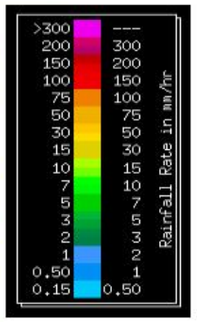


2015-05-23







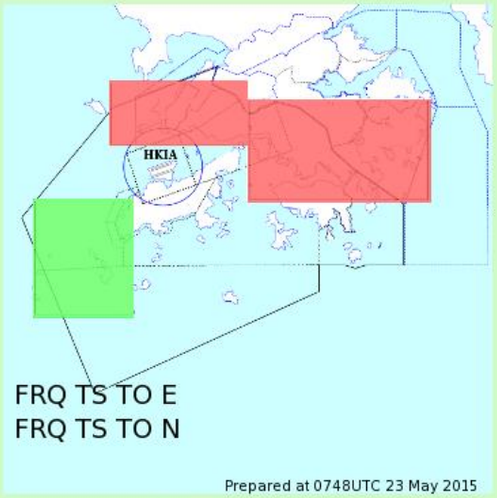


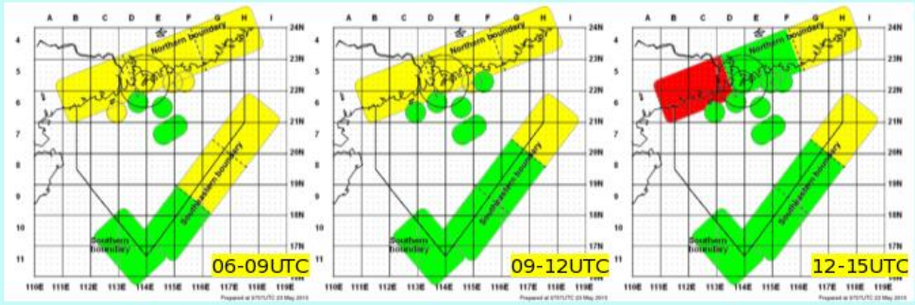
AMIDS

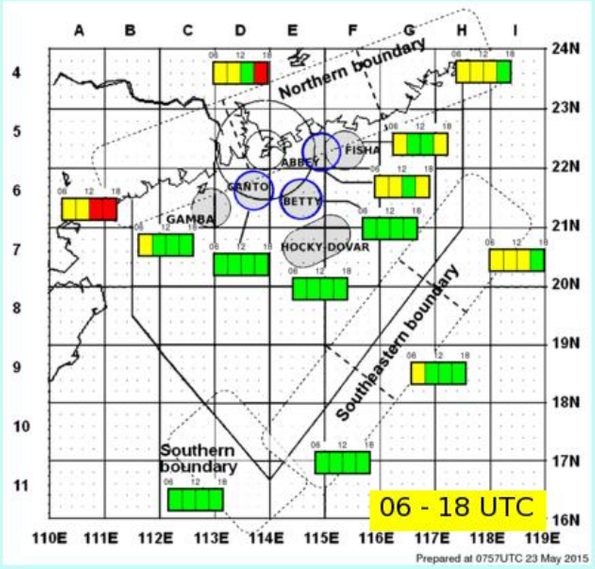
Significant Convection Monitoring and Forecast (trial)

Forecast valid from 06 UTC 23 May 2015 to 18 UTC 23 May 2015

07:48 - 08:48 UTC







Forecast for HKIA

UTC	08	09	10	11	12	13	14	15	16
Overall									
07 Headwind									
25 Headwind									
Crosswind									
Visibility									
Ceiling									

Prepared at 0750UTC 23 May

TS/CB forecast for adjacent areas

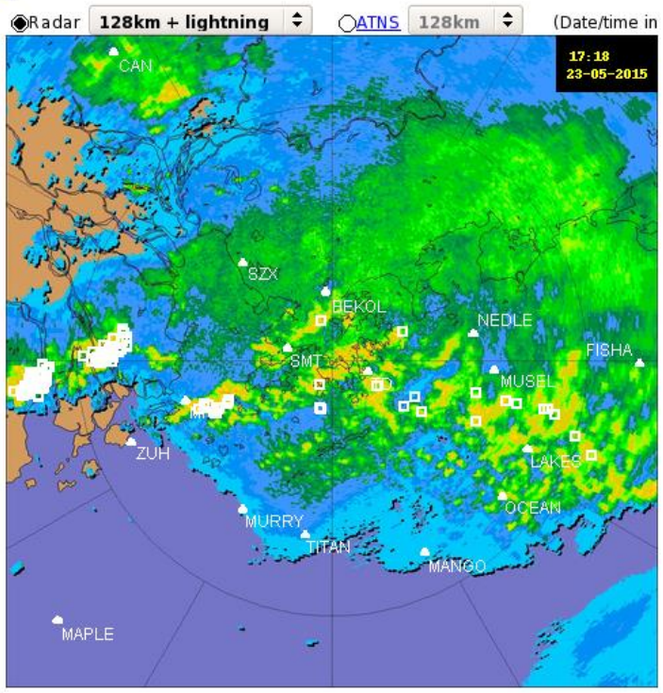
UTC	08-09	09-10	10-11	11-14
20nm of ARP				
ABBEY				
BETTY				
CANTO				

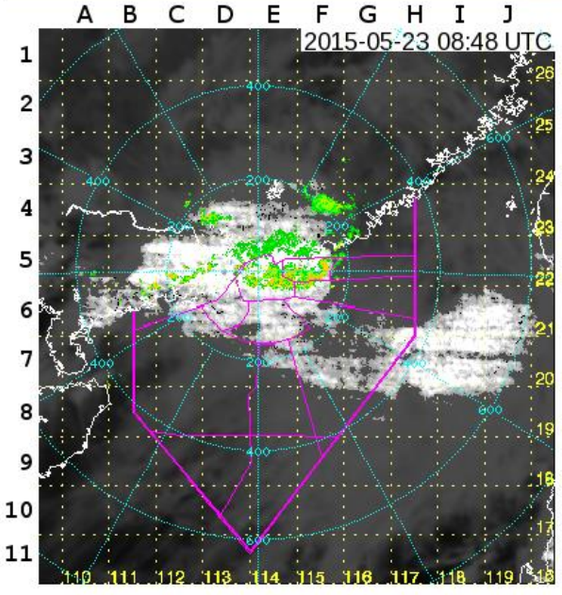
Prepared at 0757UTC

CAPACITY RELATED INFORMATION VHHH (FOR ARRIVALS)
VALID: 230800 to 231600 UTC
CAPACITY LEVEL: 1
AIRPORT ACCEPTANCE RATE: 29 flights per hour
EXPECTED DELAY: Up to 15 mins
REASON: -
REMARK: Trough of low pressure continues to affect the northern boundary of Hong Kong FIR and holding fixes ABBEY and FISHA. Holding may be in excess of 30 minutes due to traffic backlog.
Prepared at: 0515UTC 23 May 2015

Notes

2015-05-23 17:30



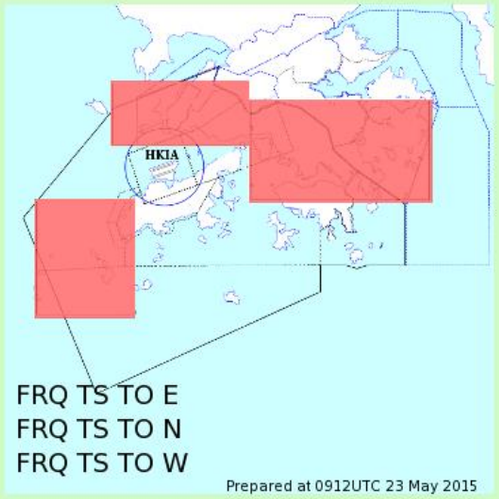


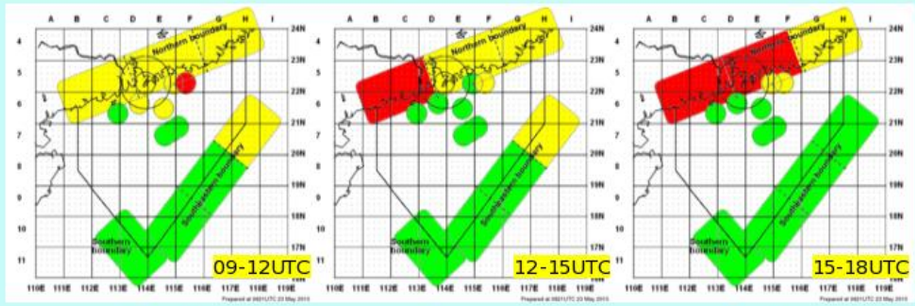
AMIDS 香港天文台 Hong Kong Observatory

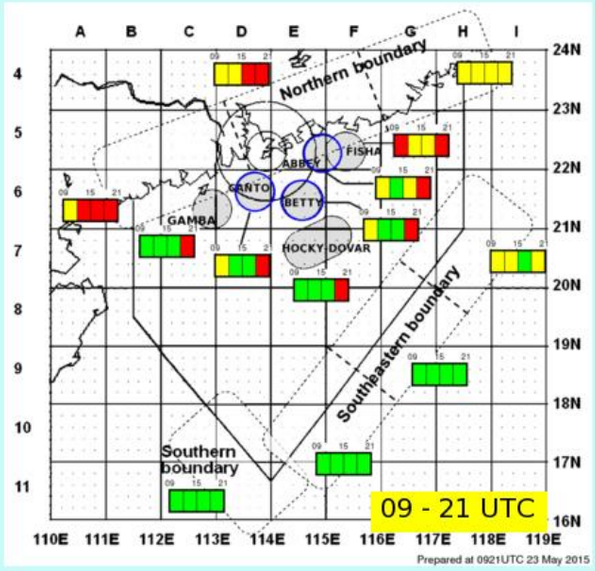
Significant Convection Monitoring and Forecast (trial)

Forecast valid from 09 UTC 23 May 2015 to 21 UTC 23 May 2015

09:12 - 10:12 UTC







Forecast for HKIA

UTC	10	11	12	13	14	15	16	17	18
Overall									
07 Headwind									
25 Headwind									
Crosswind									
Visibility									
Ceiling									

Prepared at 0918UTC 23 May

TS/CB forecast for adjacent areas

UTC	09-10	10-11	11-12	12-15
20nm of ARP				
ABBEY				
BETTY				
CANTO				

Prepared at 0921UTC

CAPACITY RELATED INFORMATION VHHH (FOR ARRIVALS)
VALID: 230800 to 231600 UTC
CAPACITY LEVEL: 1
AIRPORT ACCEPTANCE RATE: 29 flights per hour
EXPECTED DELAY: Up to 15 mins
REASON: -
REMARK: Trough of low pressure continues to affect the northern boundary of Hong Kong FIR and holding fixes ABBEY and FISHA. Holding may be in excess of 30 minutes due to traffic backlog.
Prepared at: 0515UTC 23 May 2015

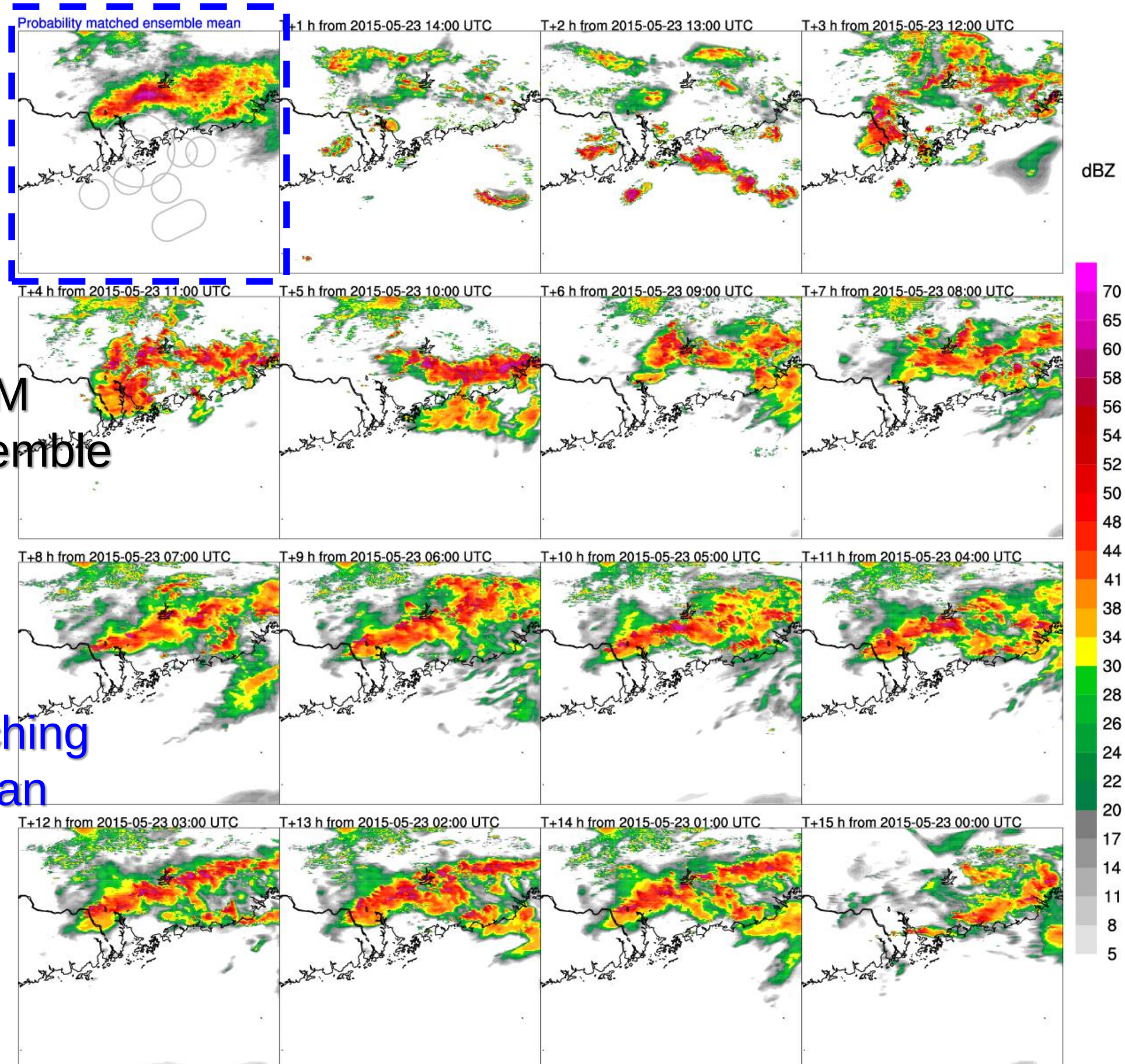
Notes

香港天文台
HONG KONG OBSERVATORY

RAPIDS-NHM
Time-lagged ensemble

2015-05-23 15:00 UTC (SAT)

Simulated Reflectivity
at 3 km level



RAPIDS-NHM
time-lagged ensemble
stamp map

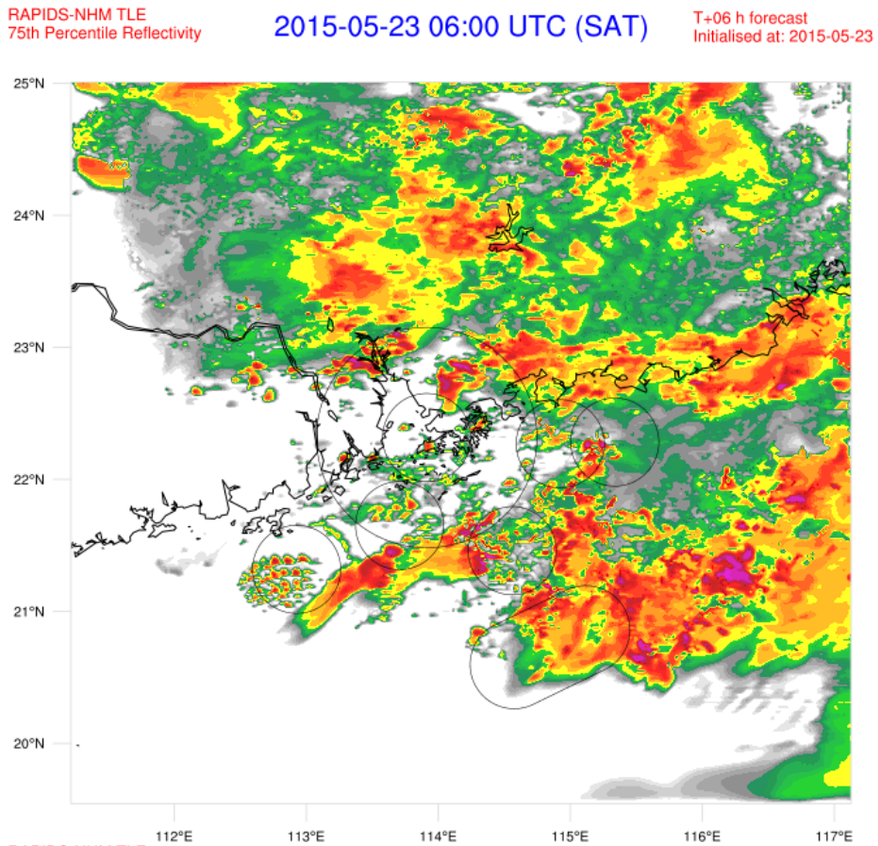
and

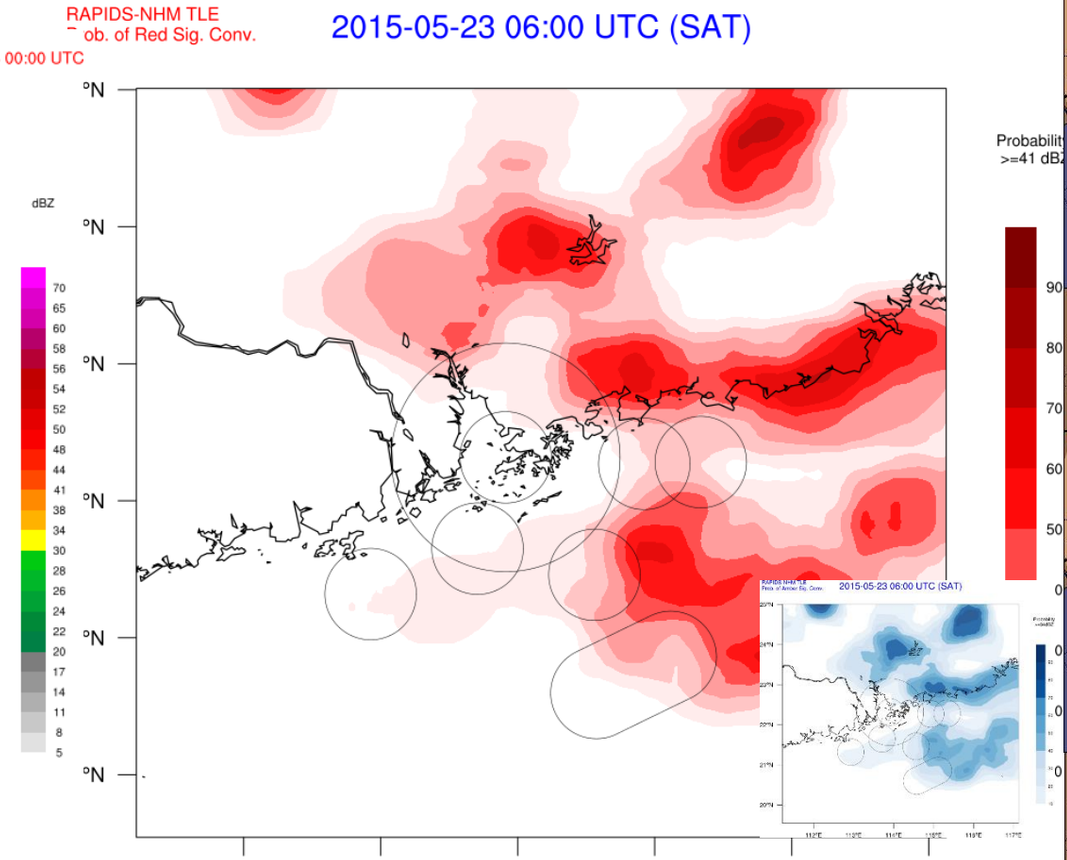
probability matching
ensemble mean

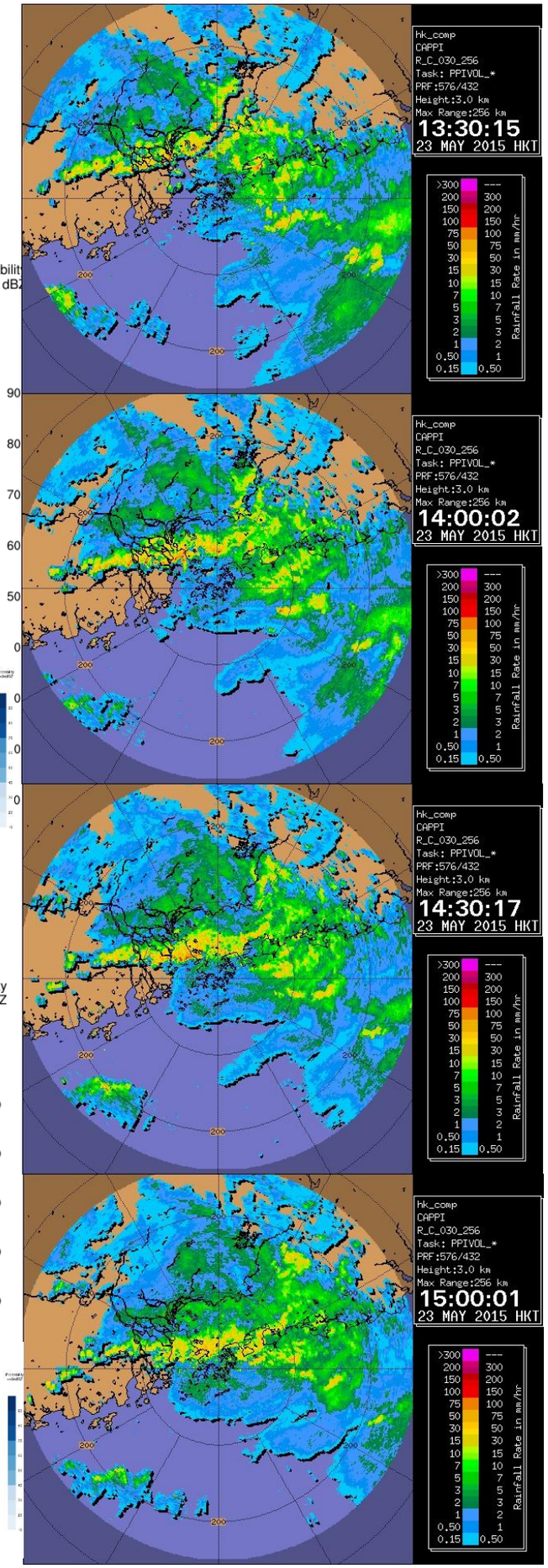
香港天文台
HONG KONG OBSERVATORY

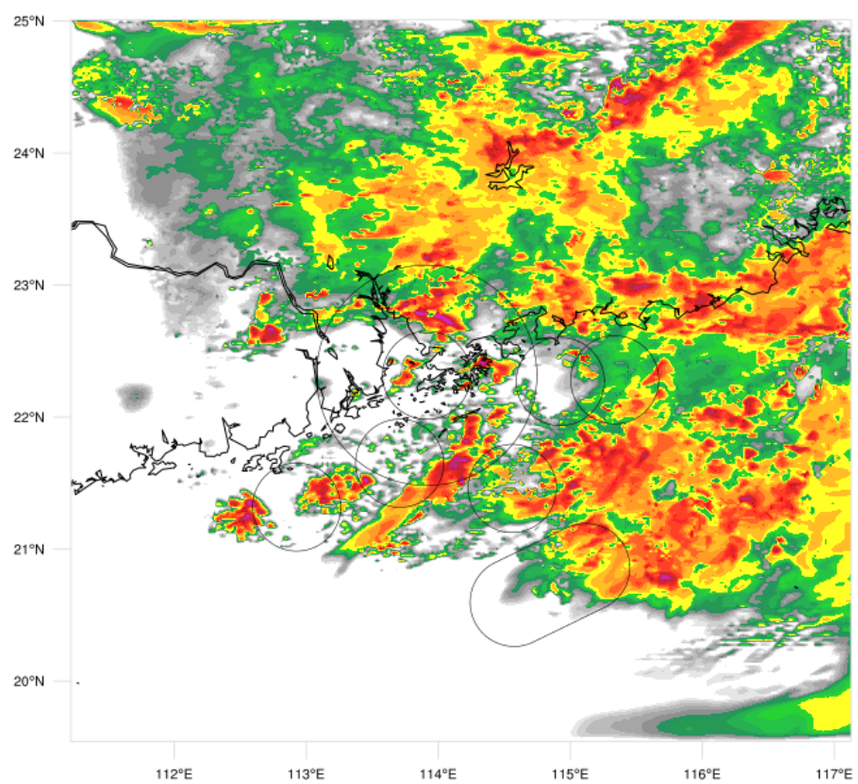
75-th percentile

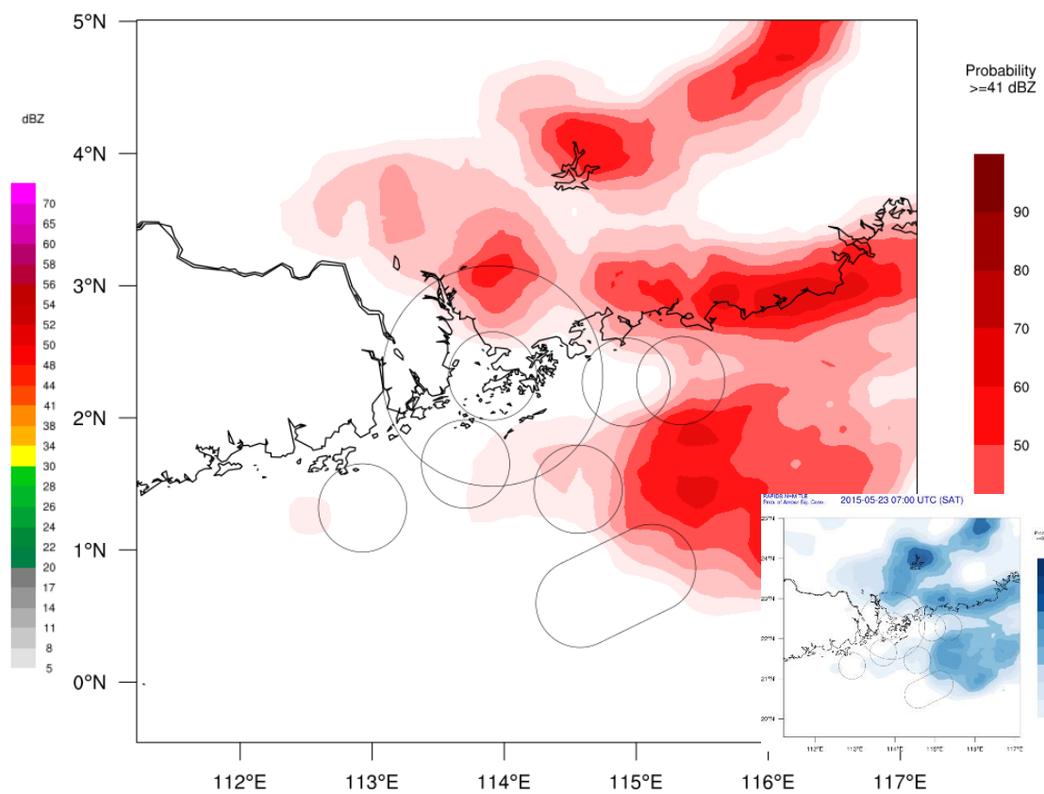
FSS-based probability of >41dBZ







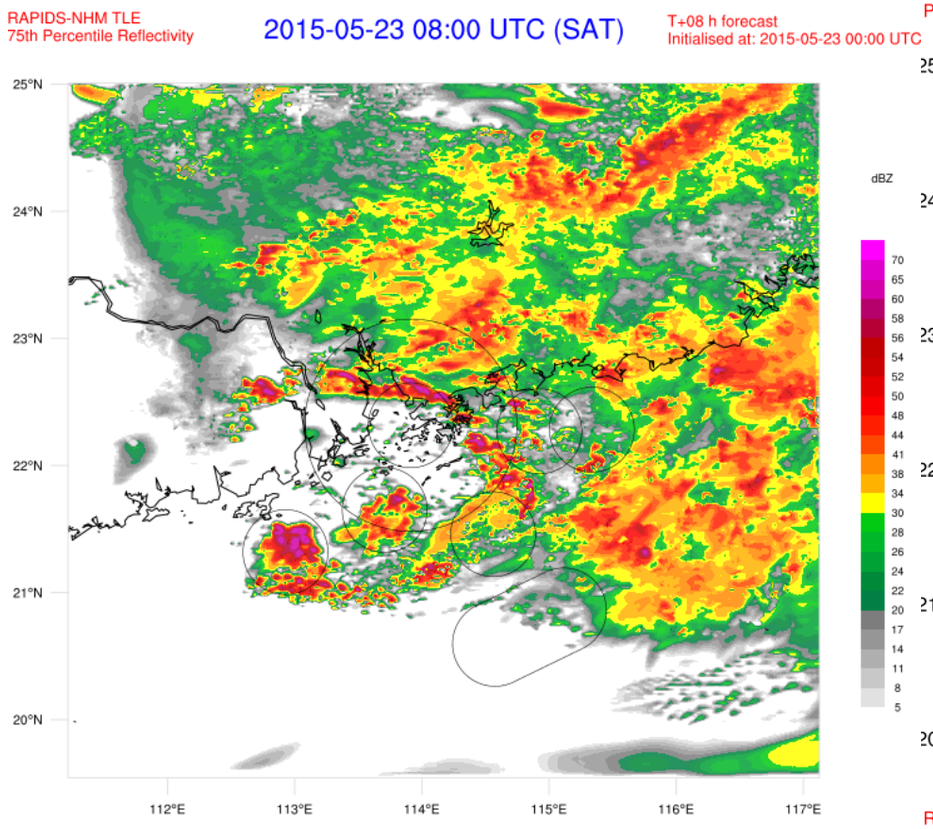


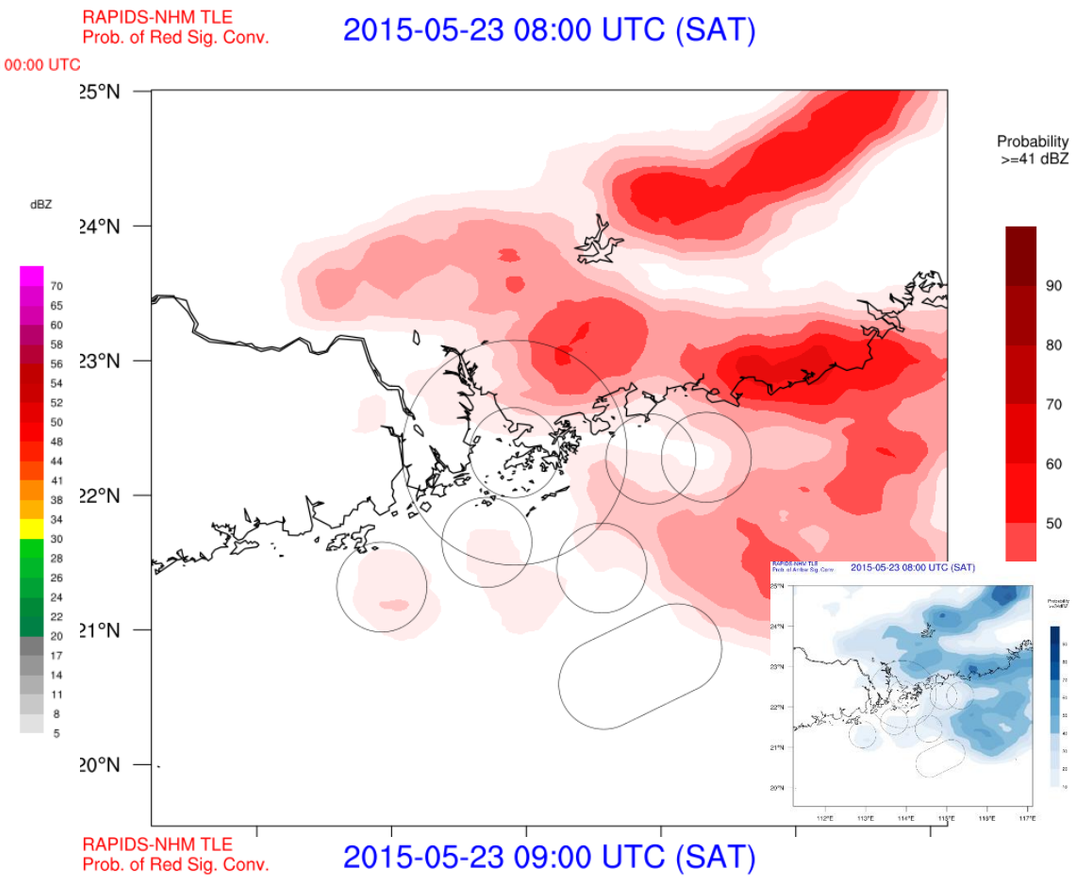


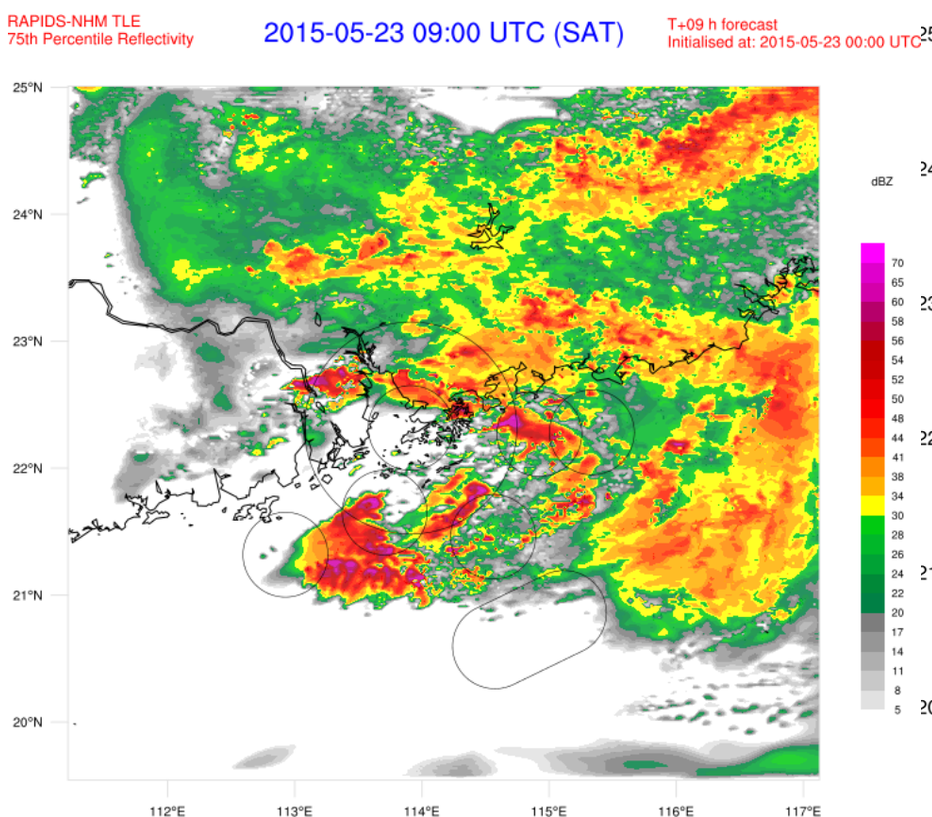
香港天文台
HONG KONG OBSERVATORY

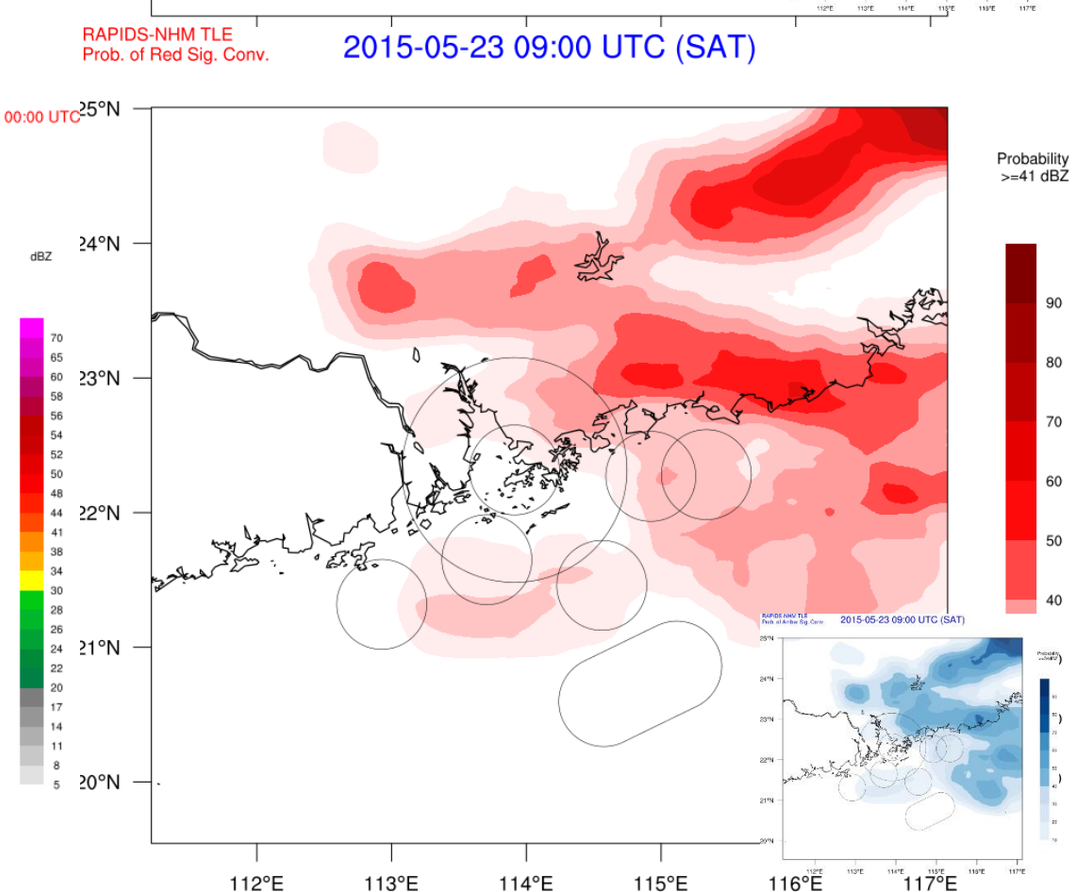
75-th percentile

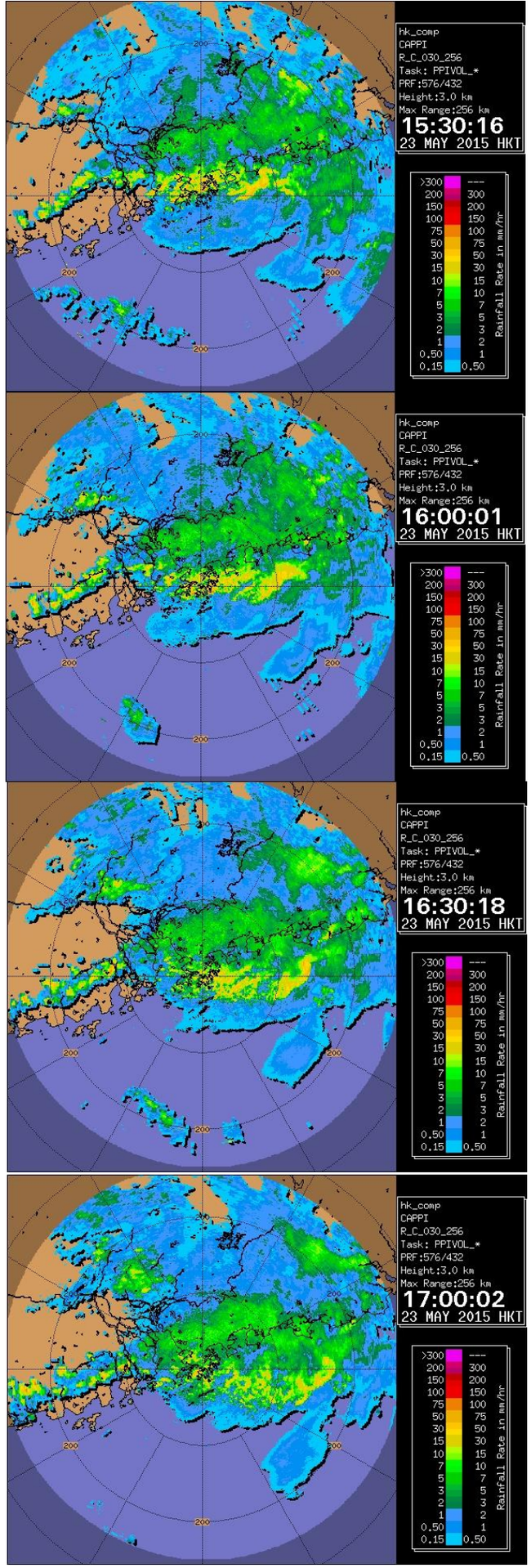
FSS-based probability of >41dBZ







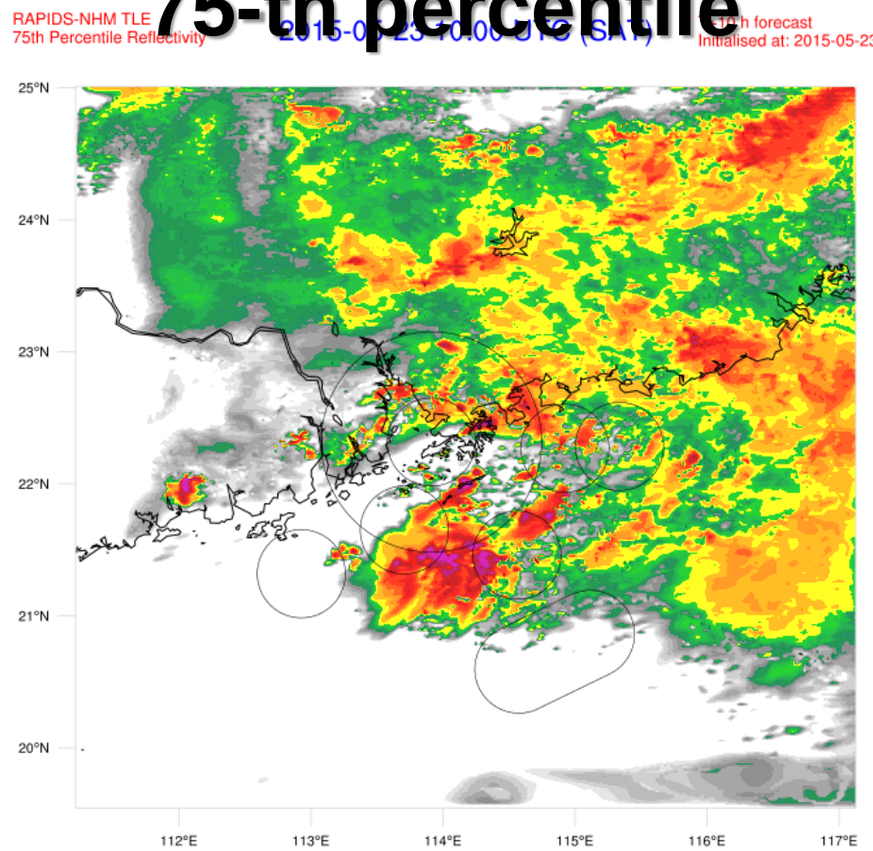


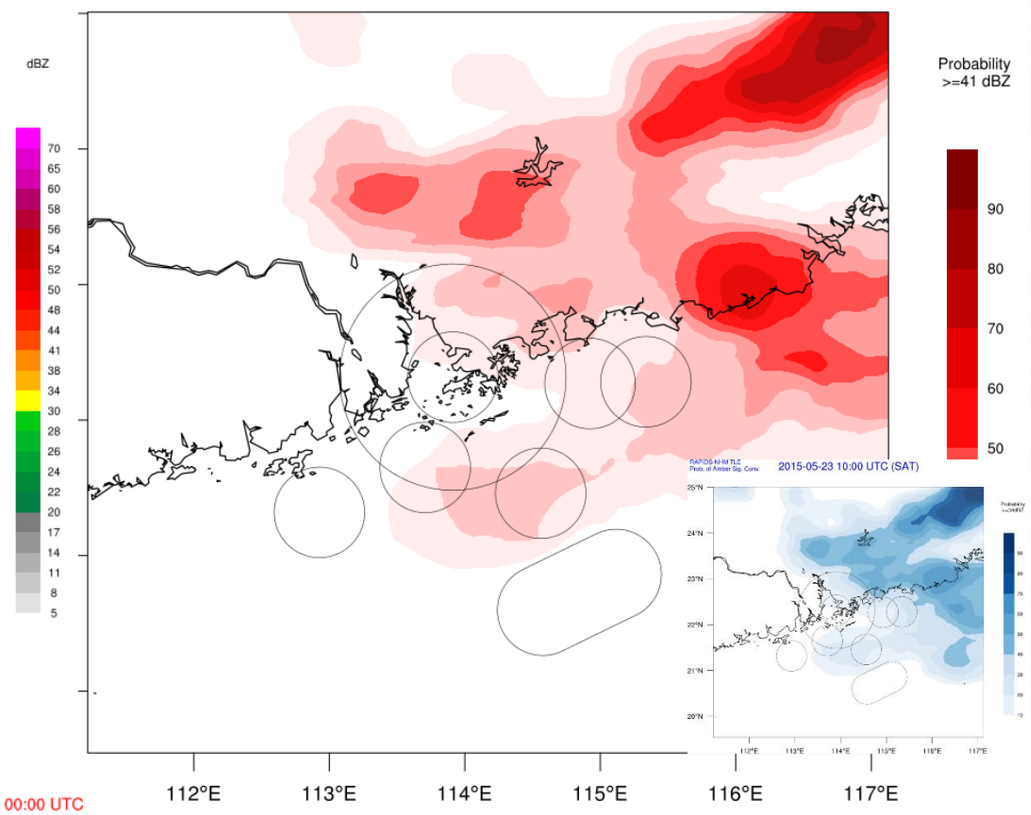


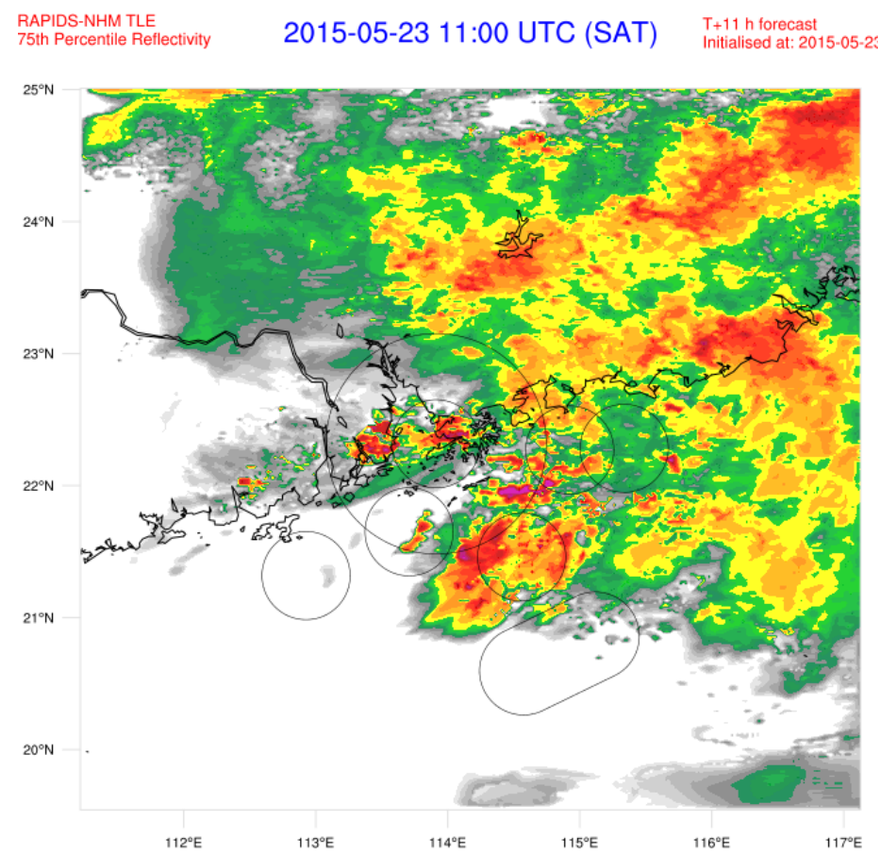
香港天文台
HONG KONG OBSERVATORY

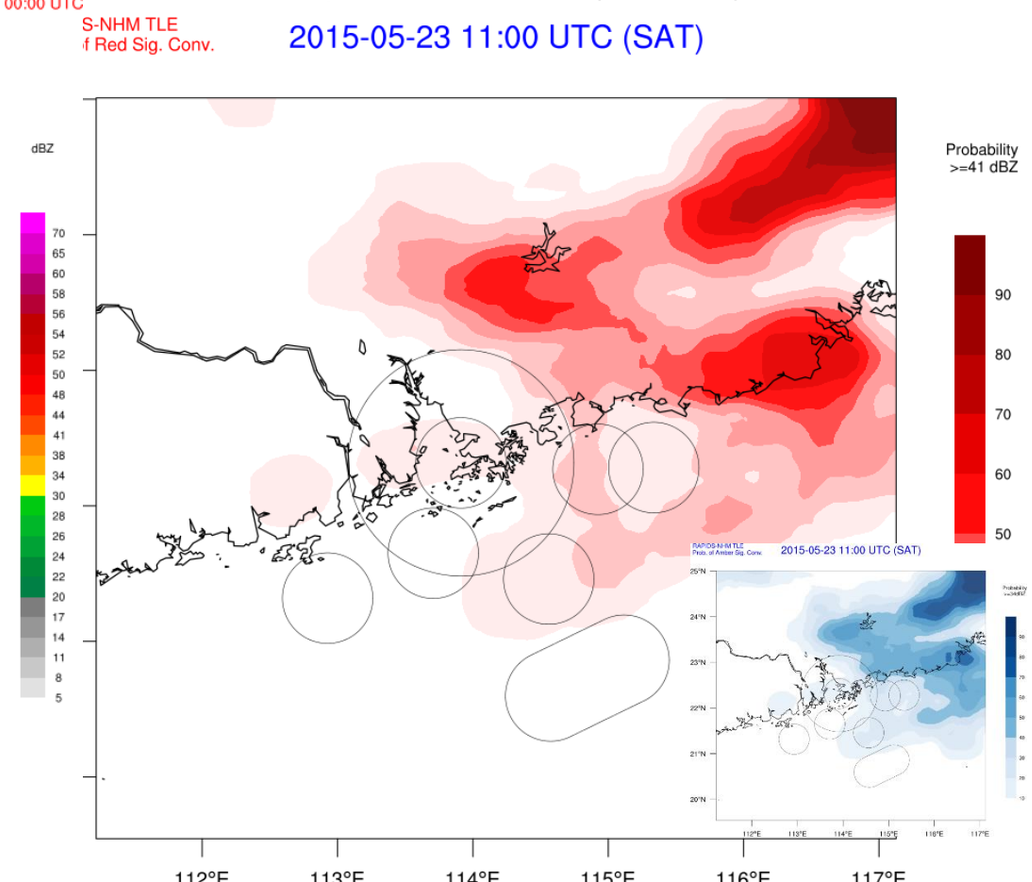
75-th percentile

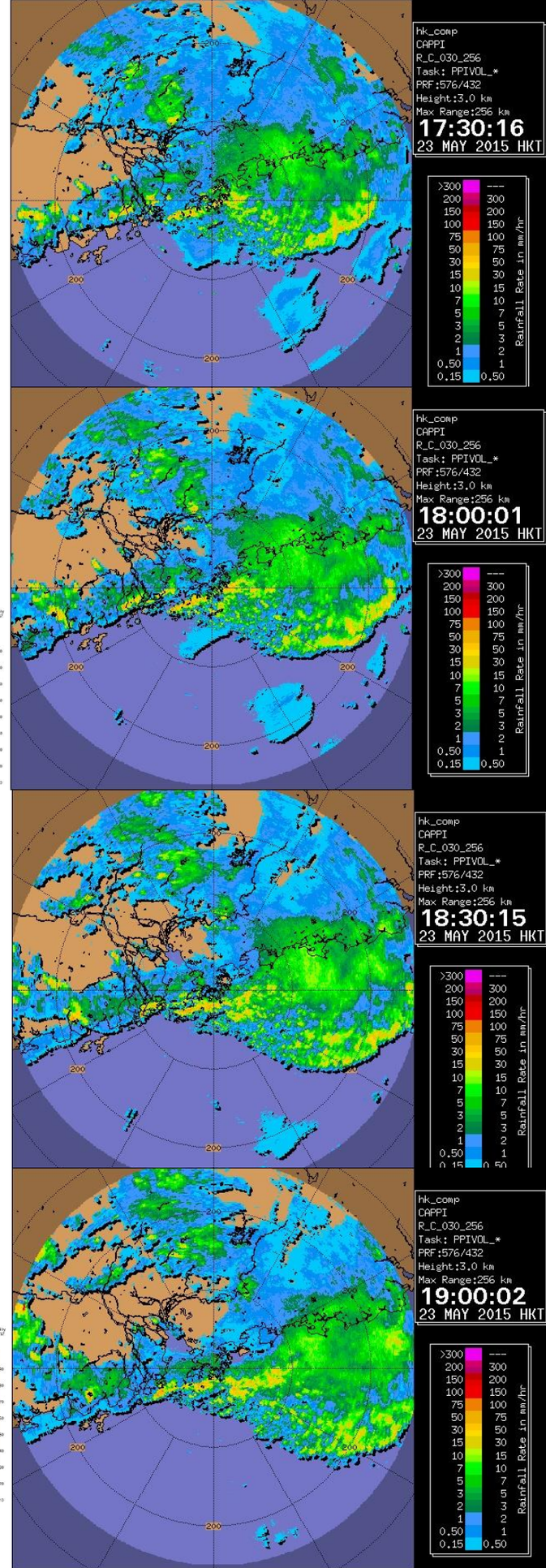
FSS-based probability of >41dBZ







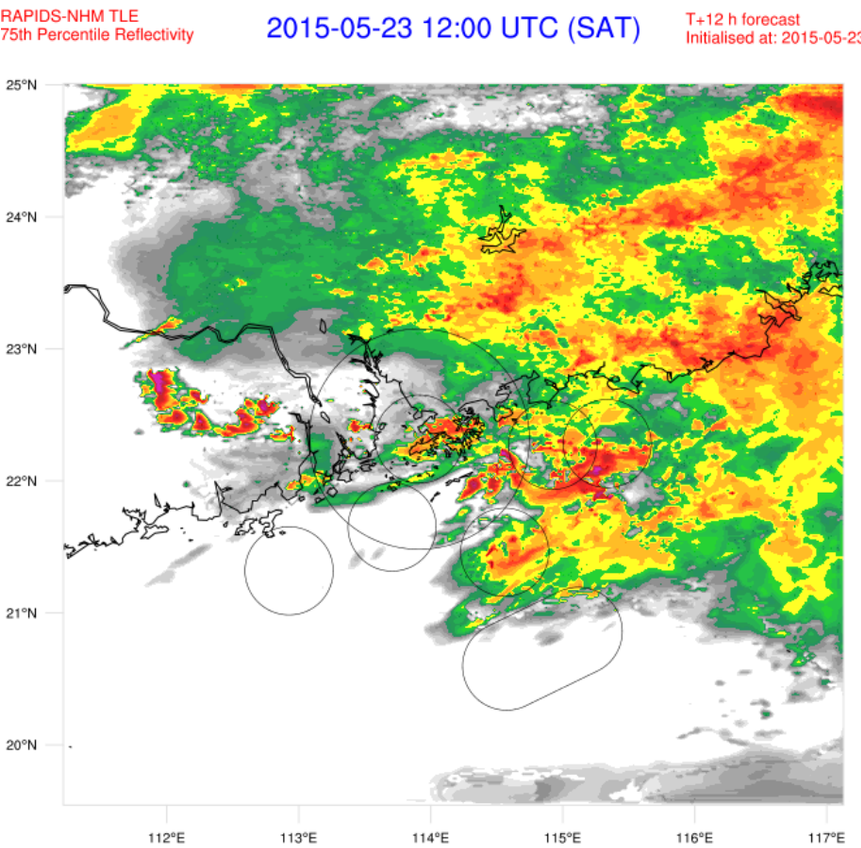


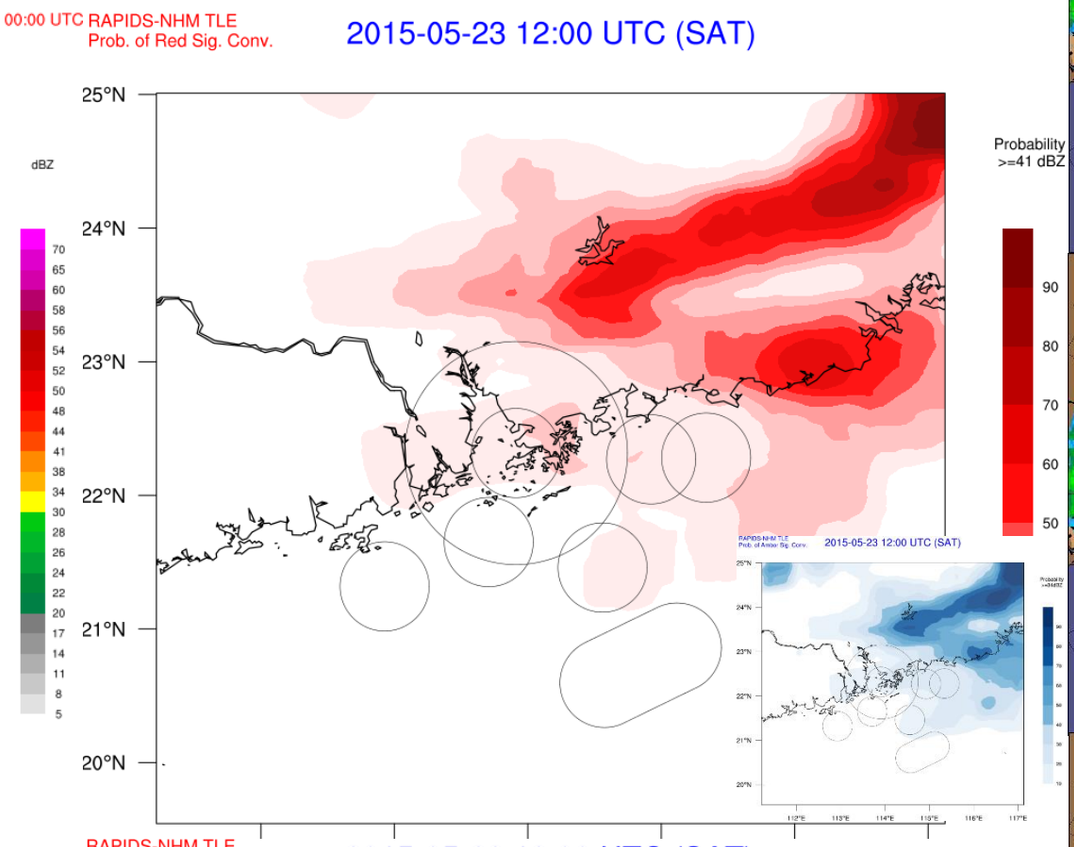


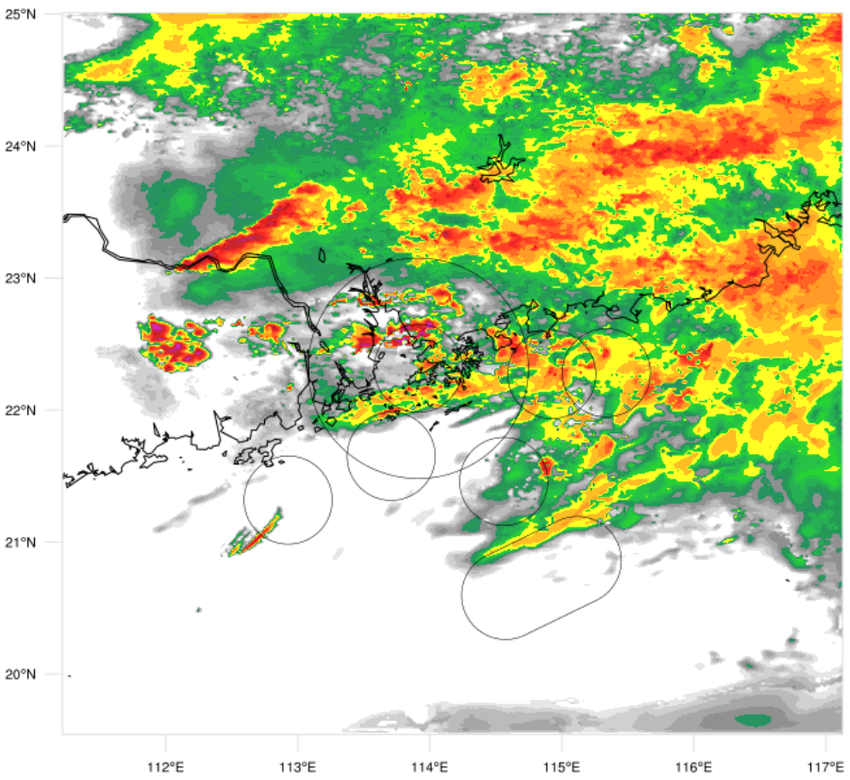
香港天文台
HONG KONG OBSERVATORY

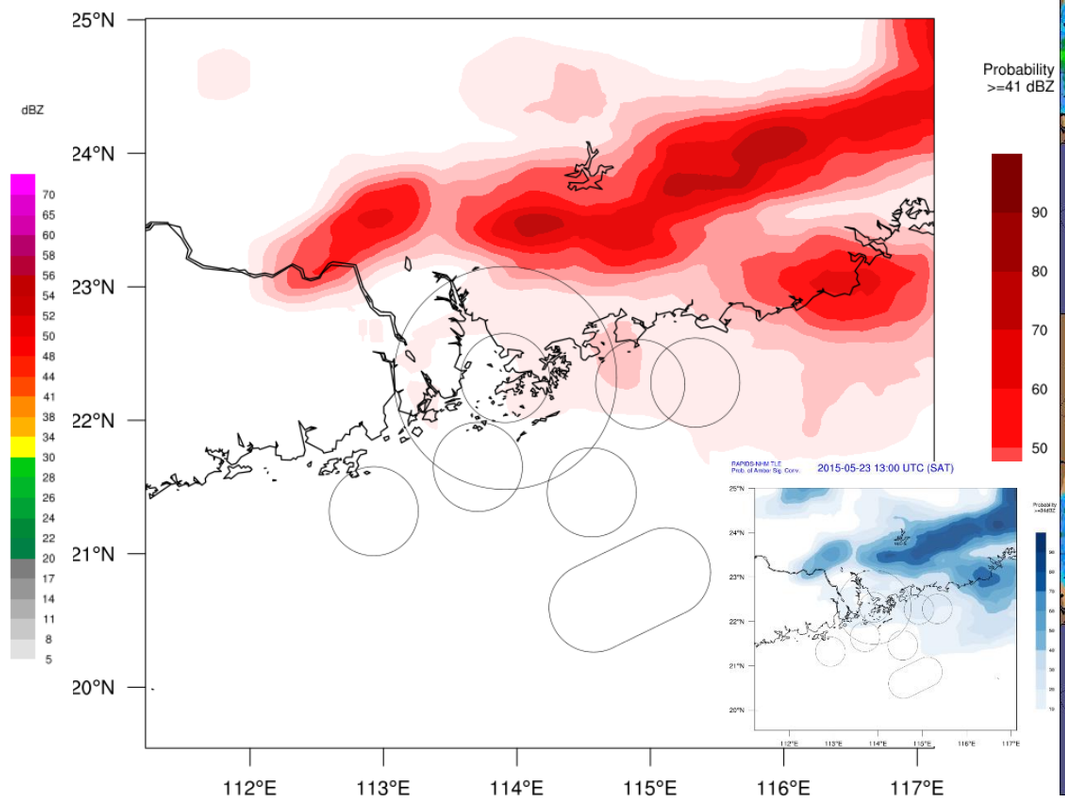
75-th percentile

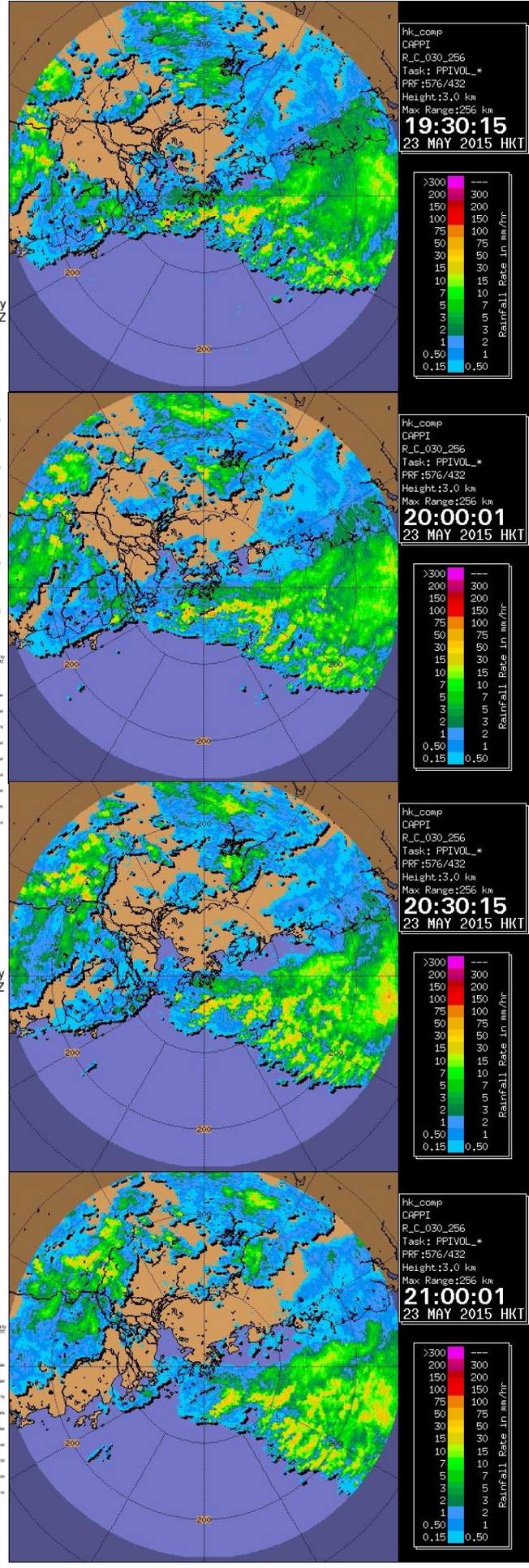
FSS-based probability of >41dBZ







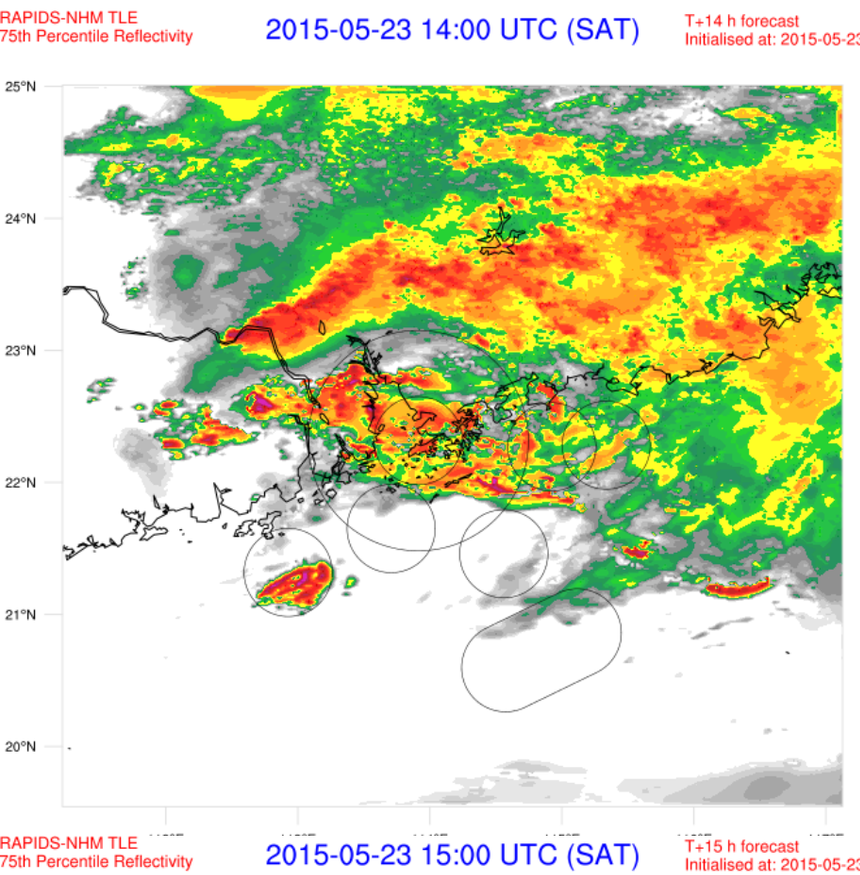


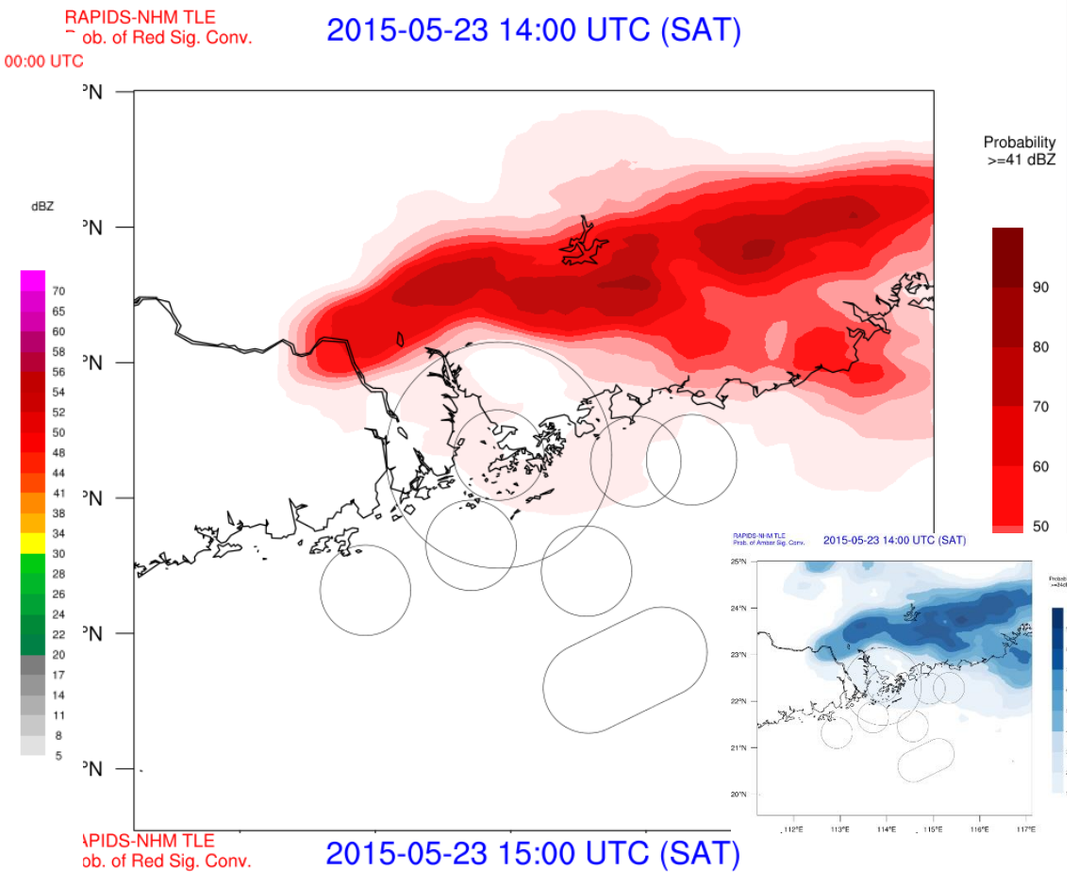


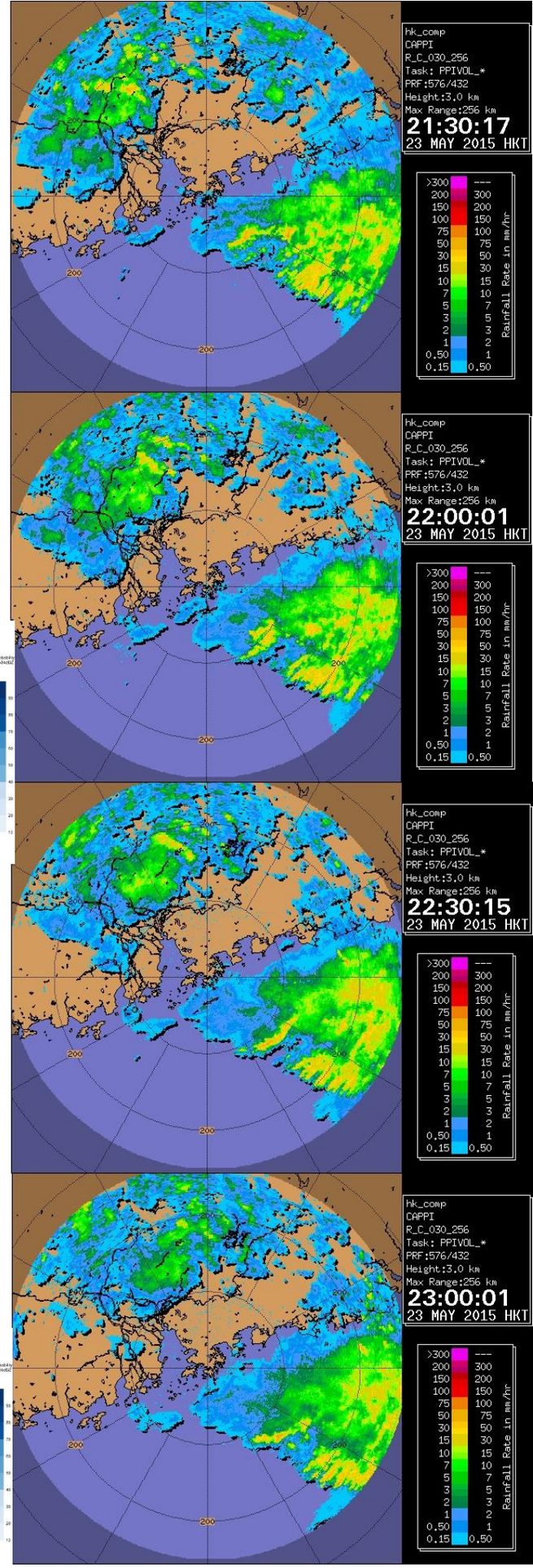
香港天文台
HONG KONG OBSERVATORY

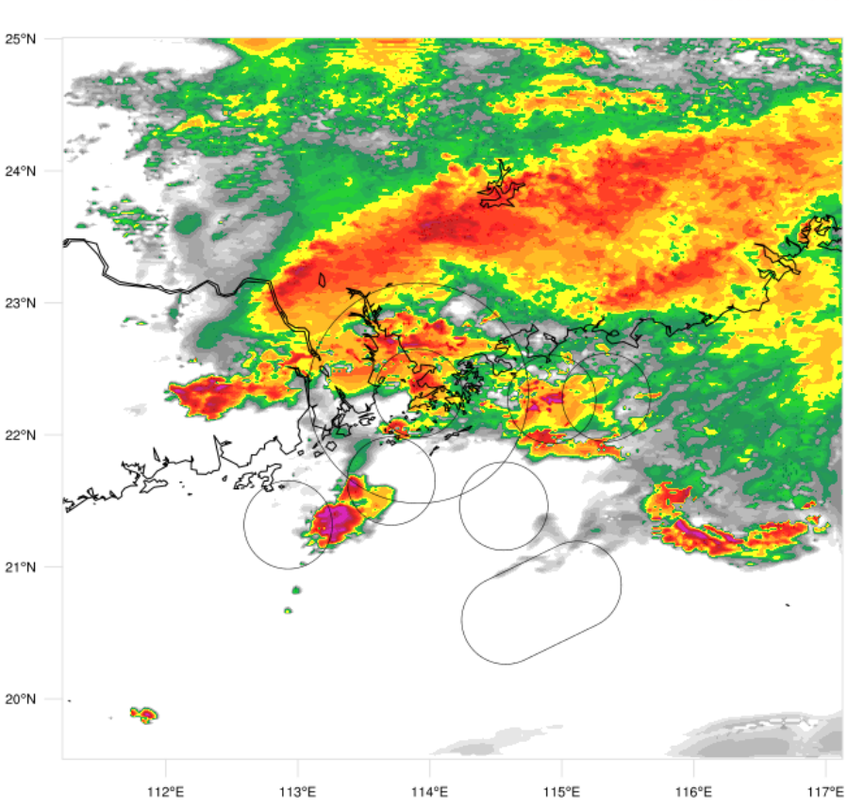
75-th percentile

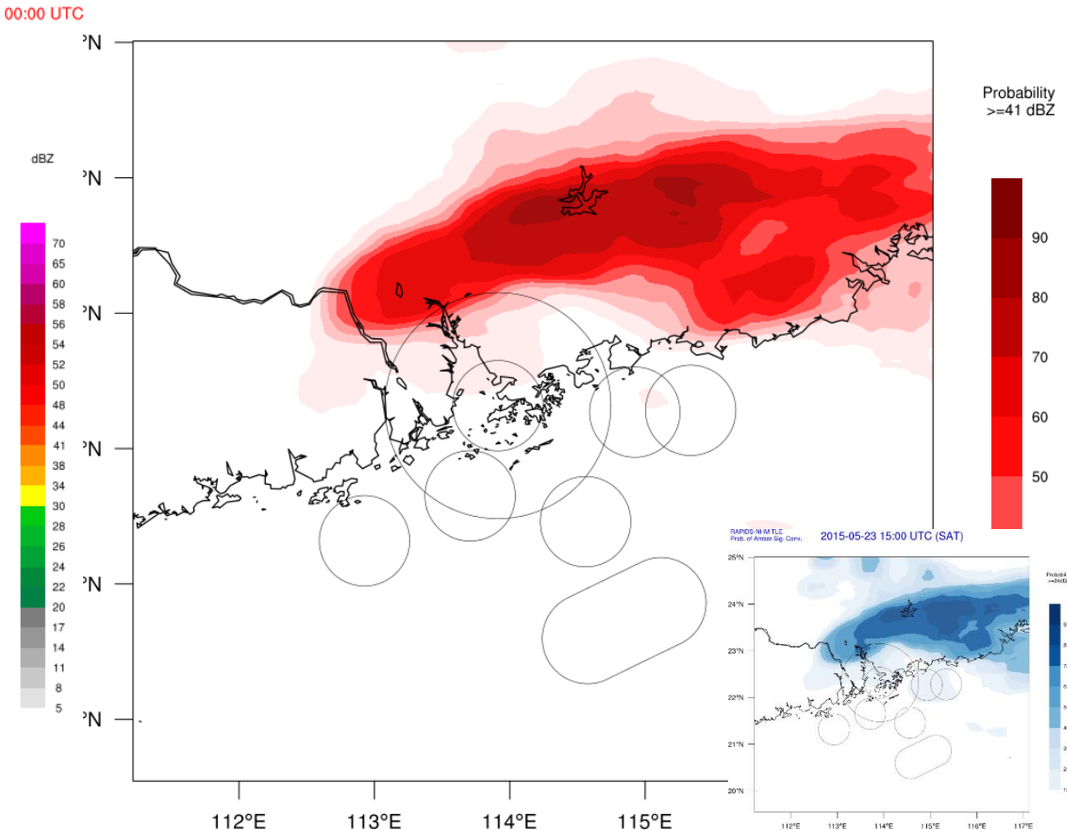
FSS-based probability of >41dBZ











Summary

- Fusion of radar extrapolated rainfall nowcast (SWIRLS) and convection-permitting, rapidly-updated NWP (RAPIDS-NHM)

- RAPIDS-NHM simulated radar products (e.g. 3 km reflectivity) using probability matched (PM) ensemble mean to provide NWP component in blending with sig. convection nowcast
  - PM ensemble mean = intensity distribution from TLE + pattern from ensemble mean
    - Extensible to other parameters such as VII & isothermal reflectivity
    - PM can be applied to a larger ensemble pool with nowcast inputs as an alternate blending method

- Probability of significant convection (e.g. > 34 or > 41 dBZ) derived from counting fraction of grids exceeding thresholds over an area determined by spatial-intensity verification score (FSS) at lead times in TLE members