

# Typhoon Committee Roving Seminar 2011

**Topic B(3) :**  
**Operational QPE/QPF**  
**– some latest R&D activities**



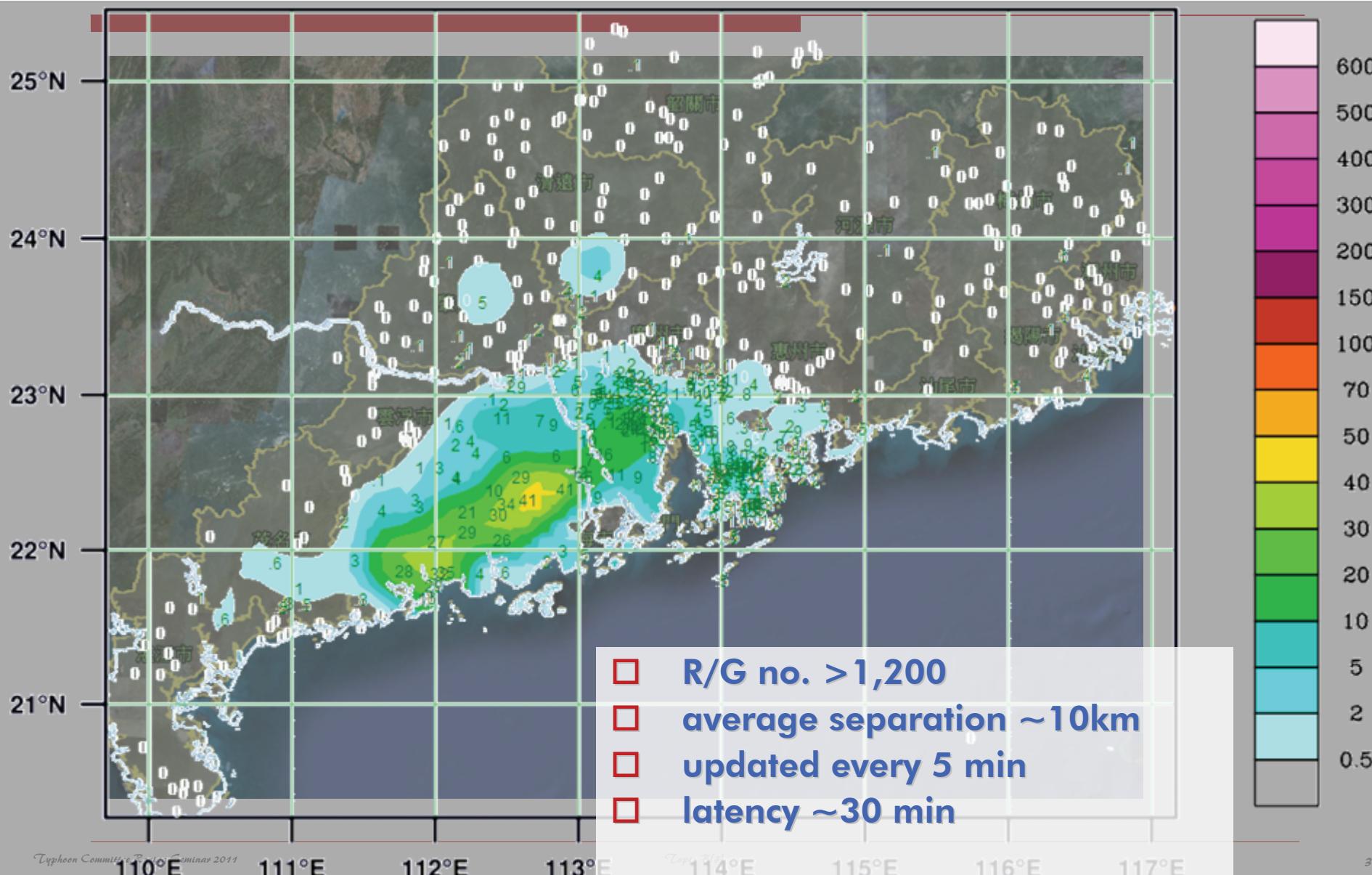
Linus H.Y. Yeung, Scientific Officer, Hong Kong Observatory  
23 September 2011  
Petaling Jaya, Malaysia

R&D

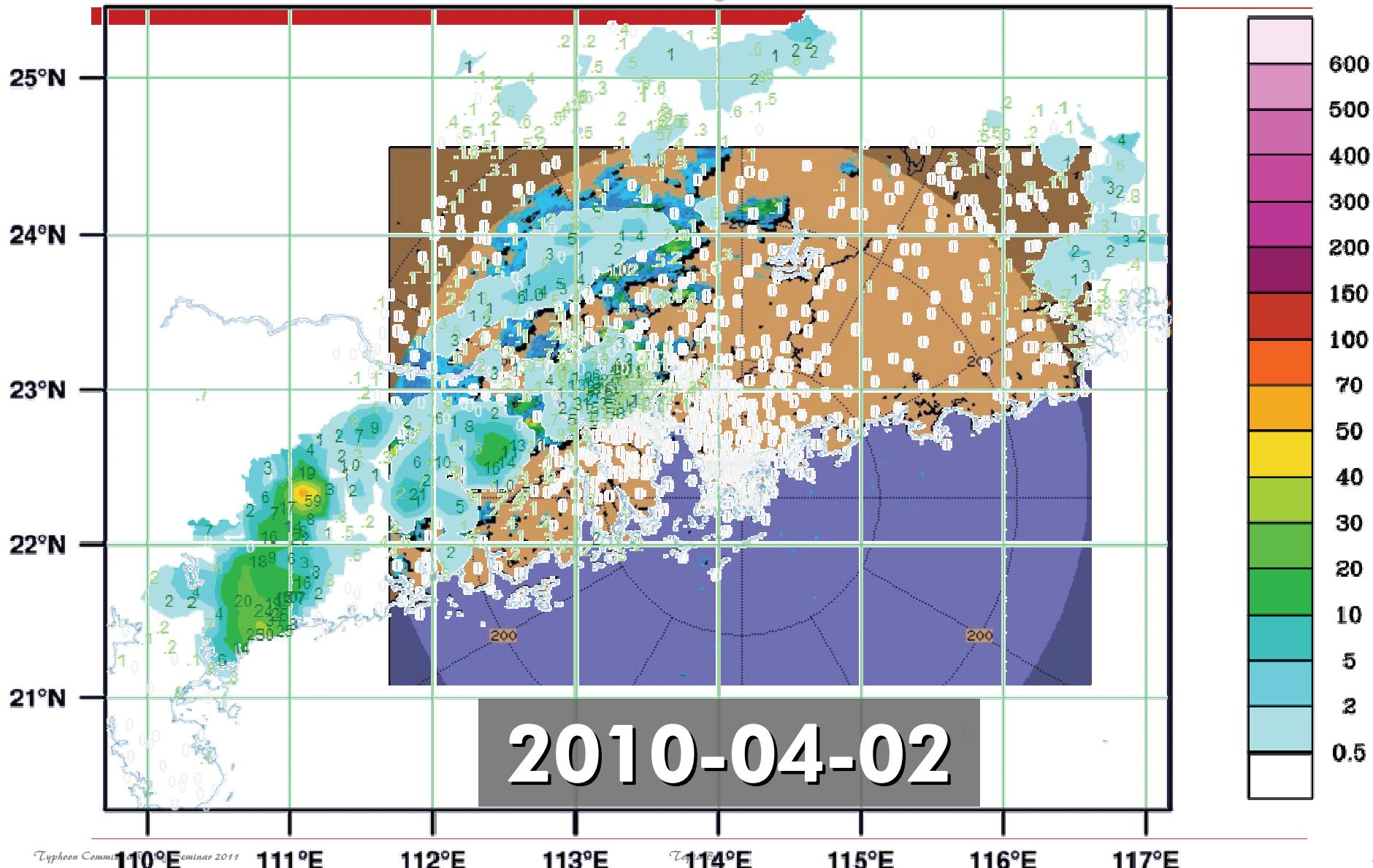
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Activities at  
HKO

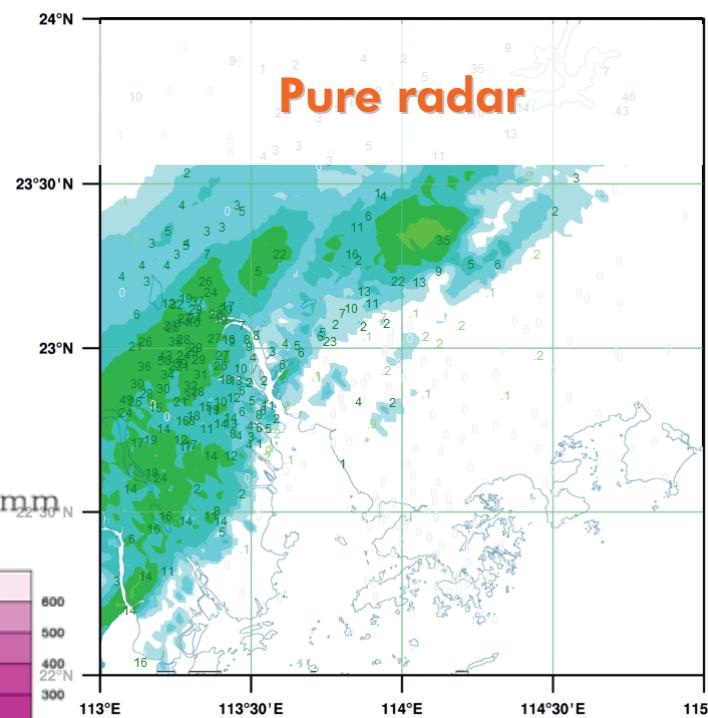
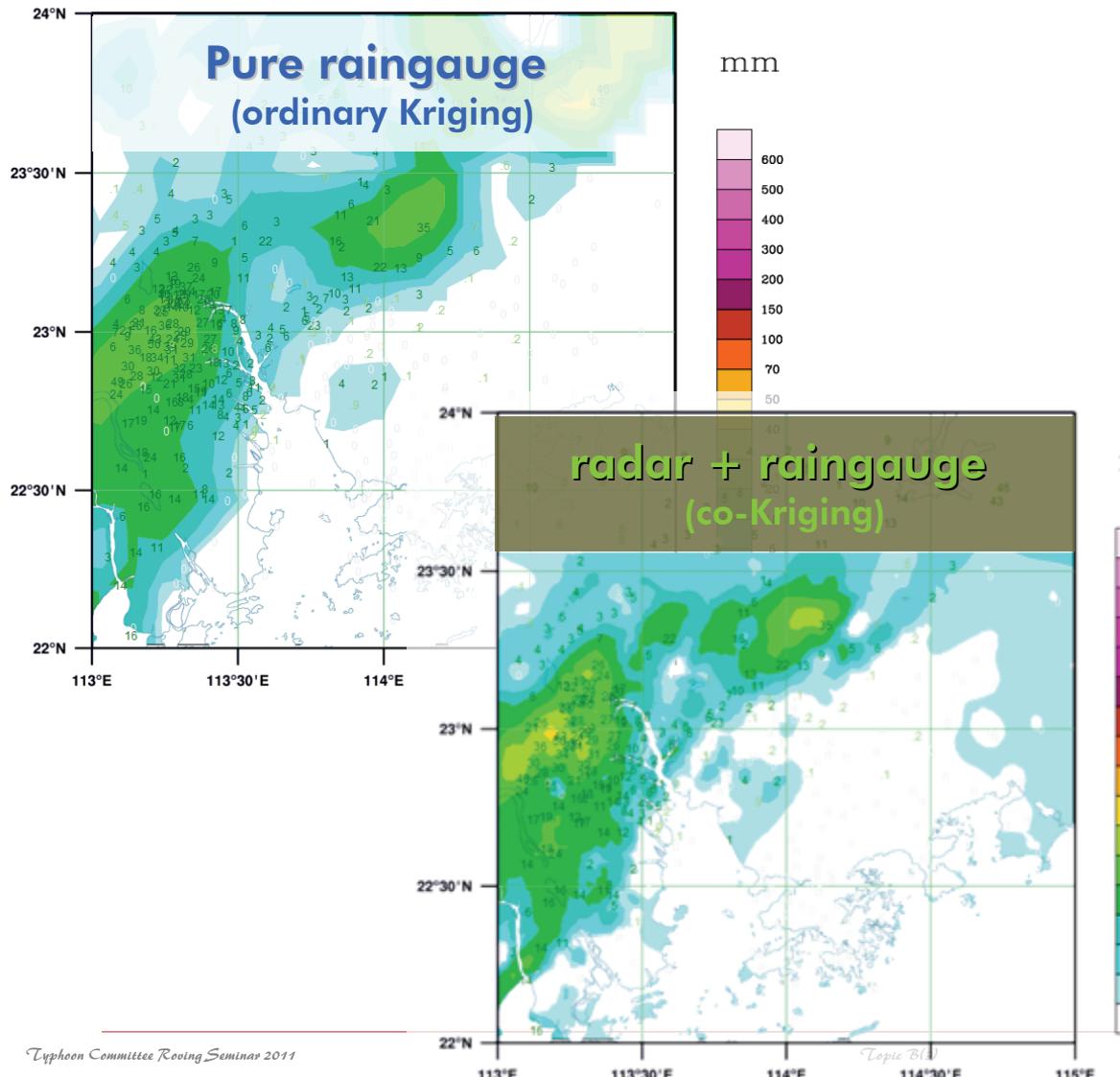
# Use of Raingauge Data



# Guangdong Rainfall Analysis

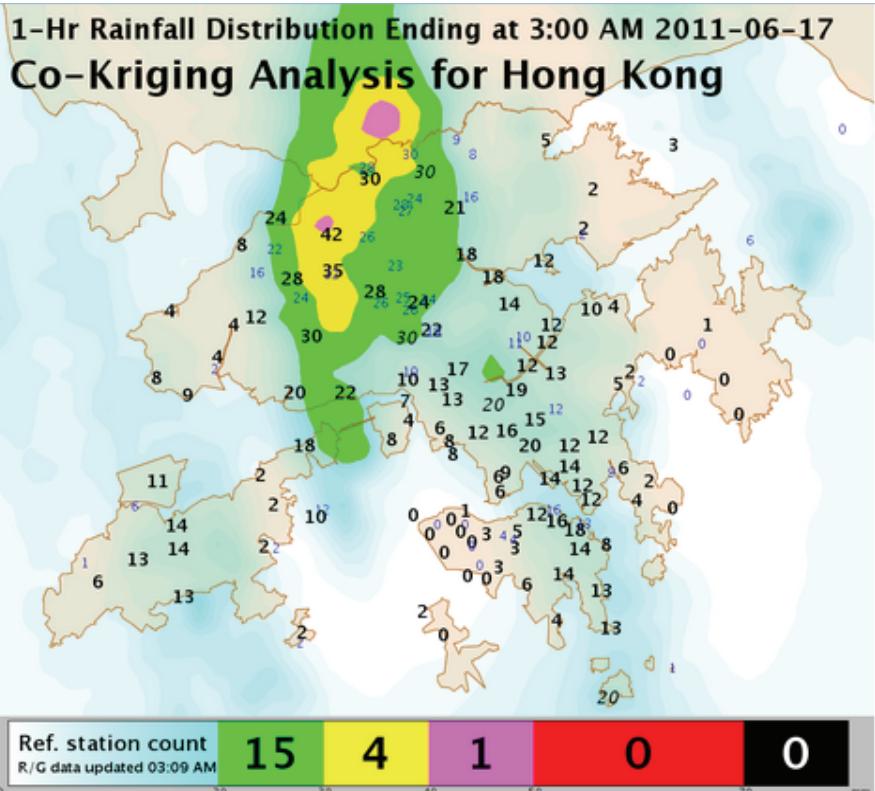
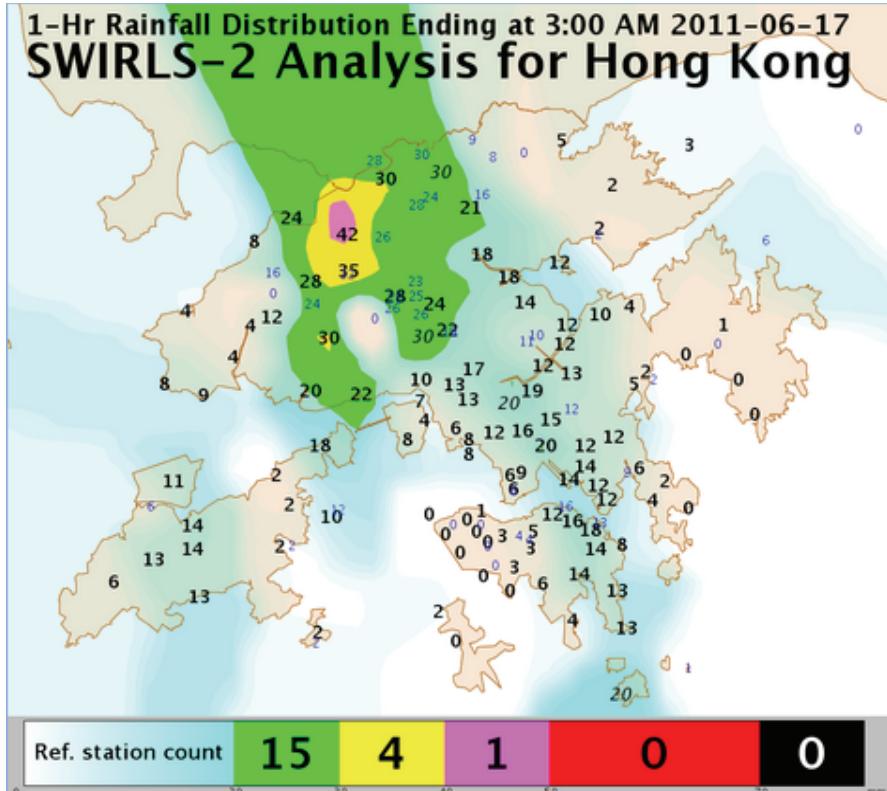


# Radar-Raingauge Blending



- for better QPE
- for rainfall data QC

# Co-Kriging QPE & Rainfall QC

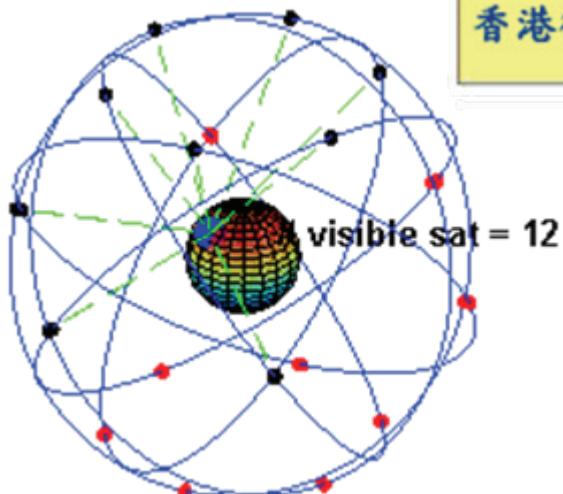


Rainguage data analysis by Barnes method  
without QC

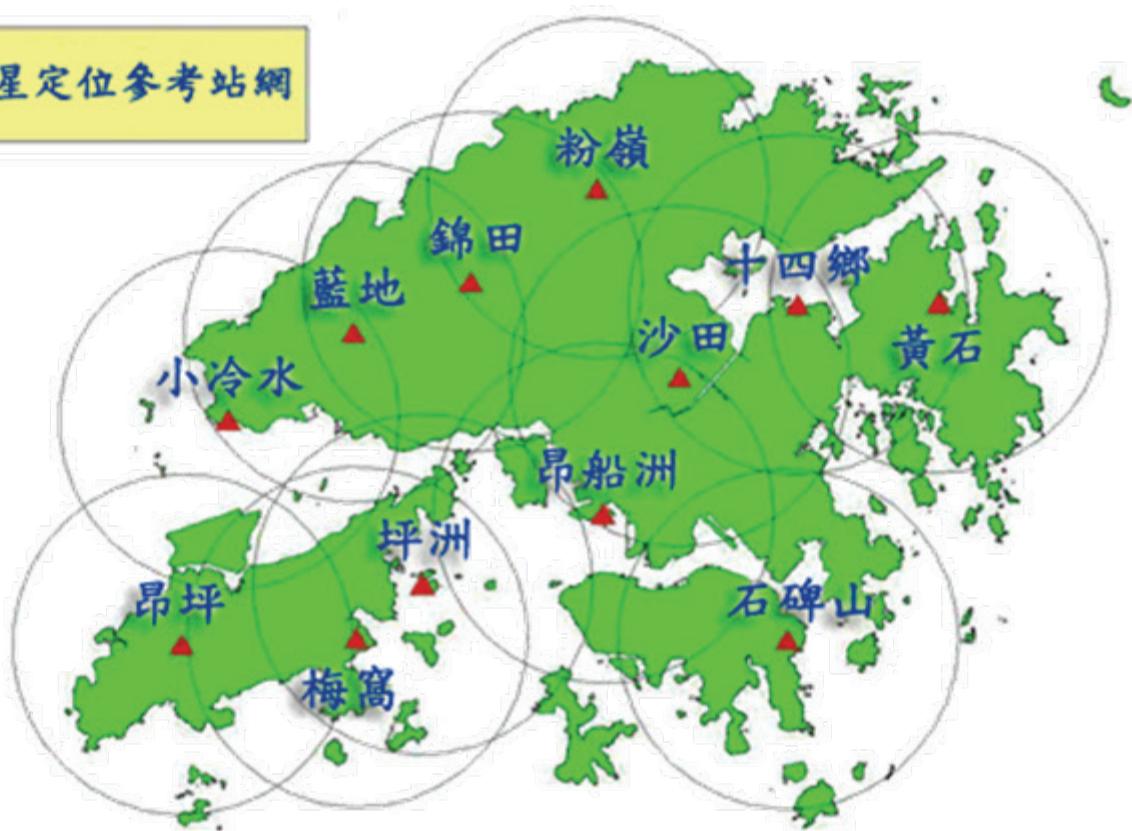
Rainguage + radar data blended analysis  
by co-Kriging method with QC

# Use of Navigation Satellite Data

- operated by the Lands Department



香港衛星定位參考站網

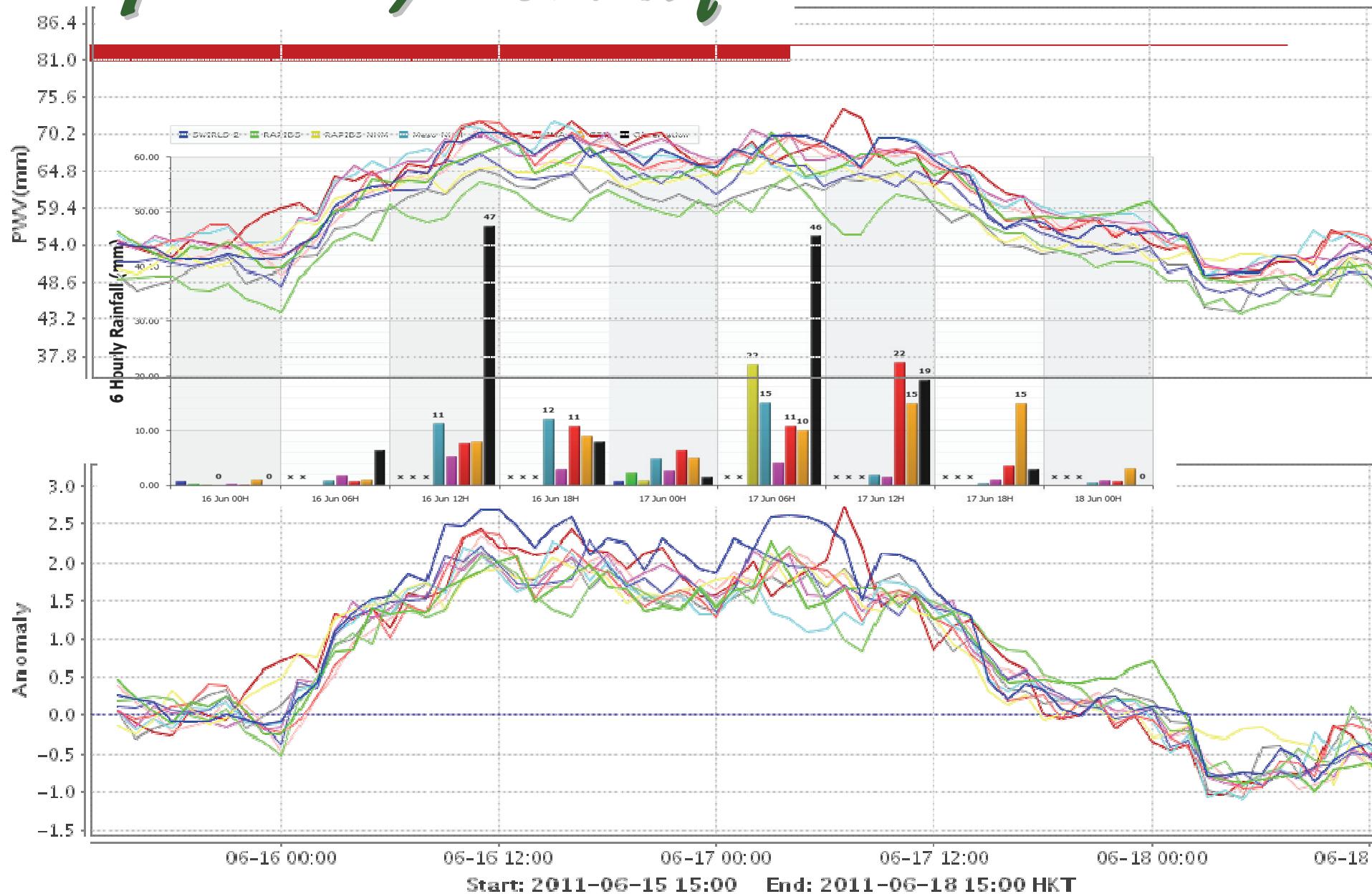


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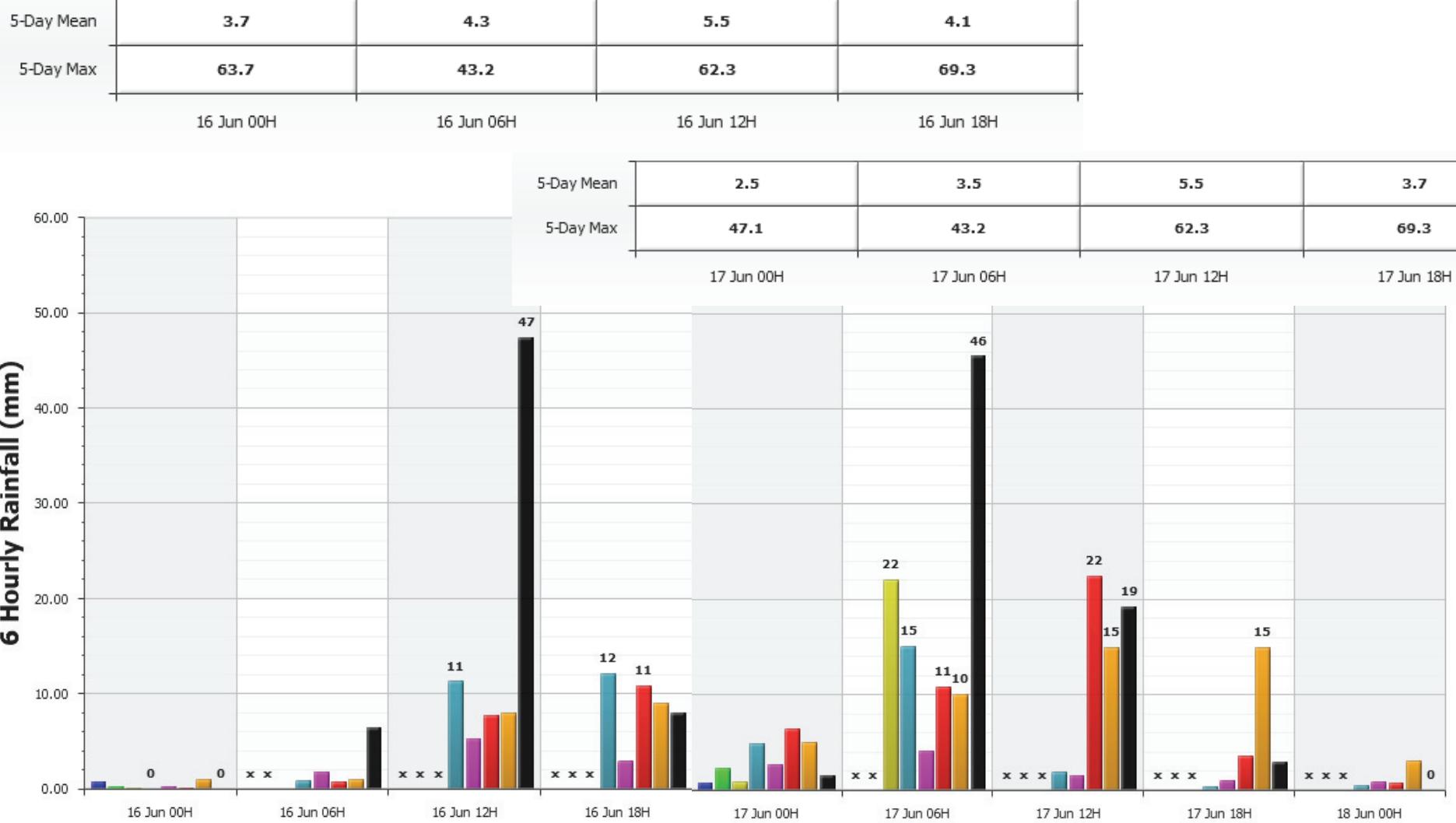


衛星定位參考站

# PWV Anomaly



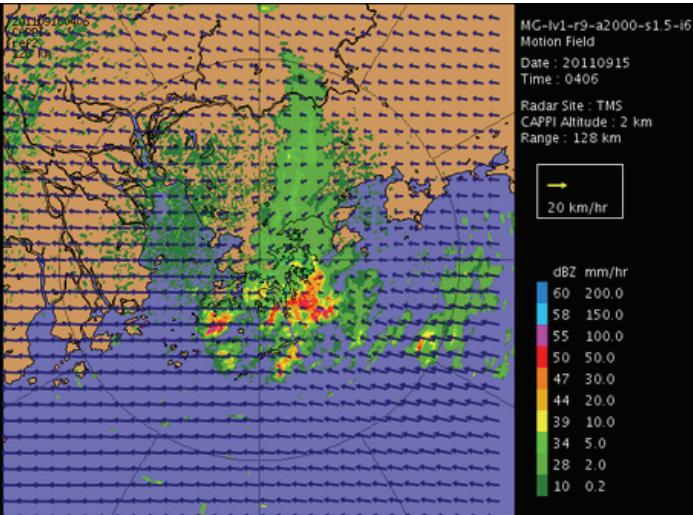
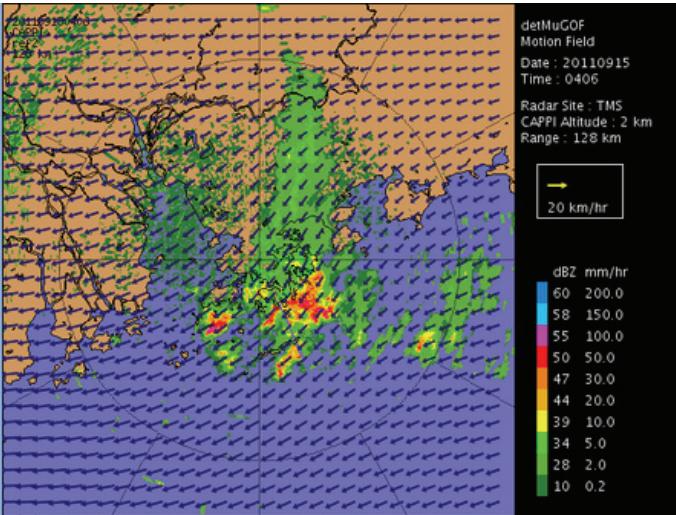
# How Extreme the Weather is?



# “Poorman” Ensemble Nowcasting

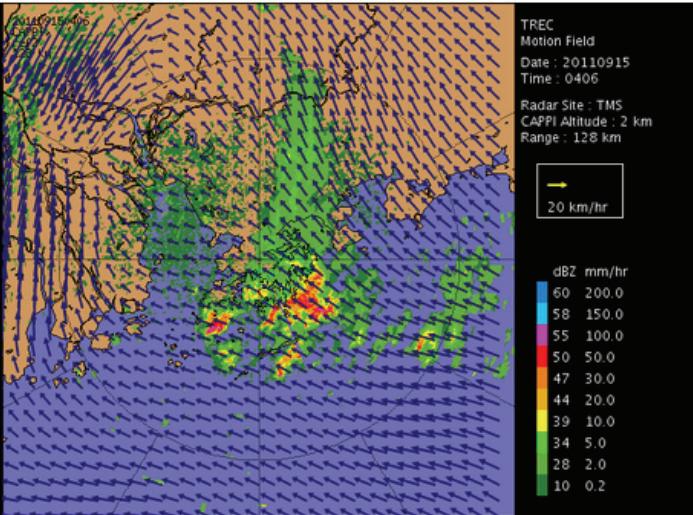
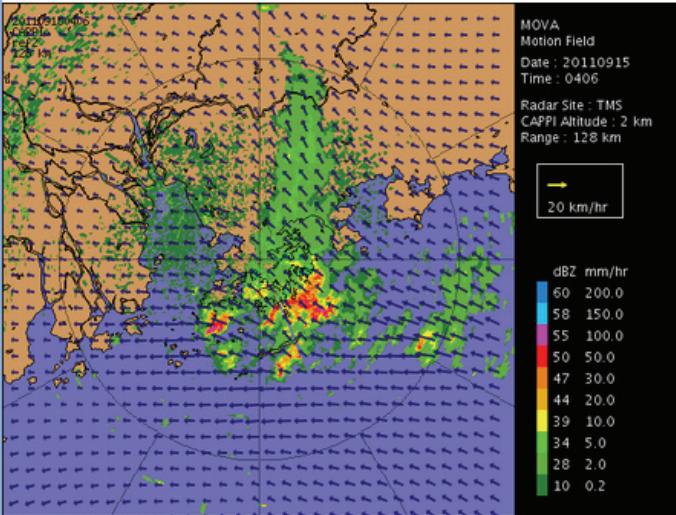
- “perturbations” on motion tracking algorithm

Poorman ensemble mean  
(4 perturbations)  
with tracking parameters)



Optical flow tracking  
(new)

Optical flow tracking  
(operational)



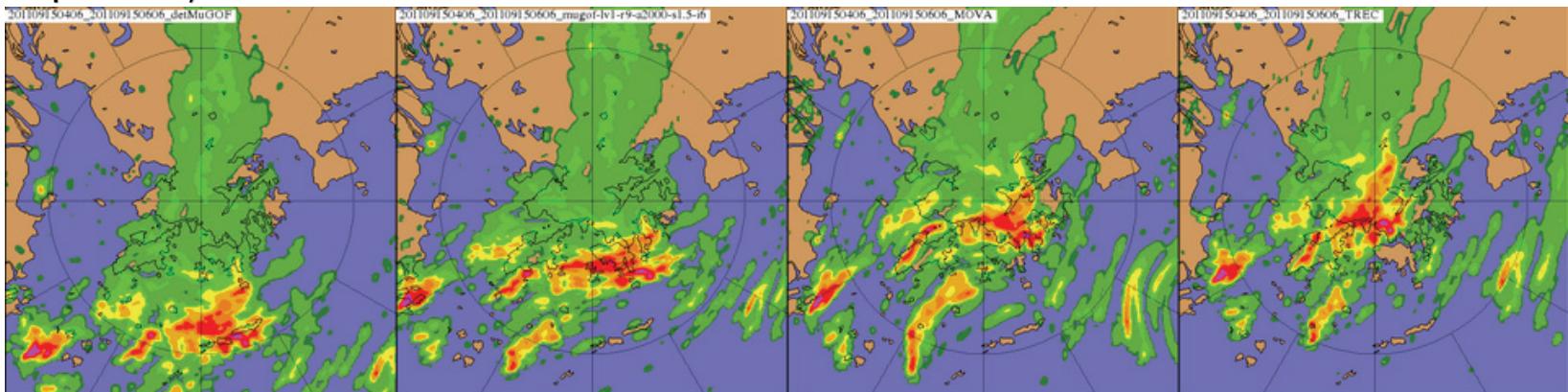
tracking of radar echoes by cross-correlation  
(TREC)

# Forecast Reflectivity at 2h

Poorman  
ensemble  
mean  
(4 perturbations)  
with tracking  
parameters)

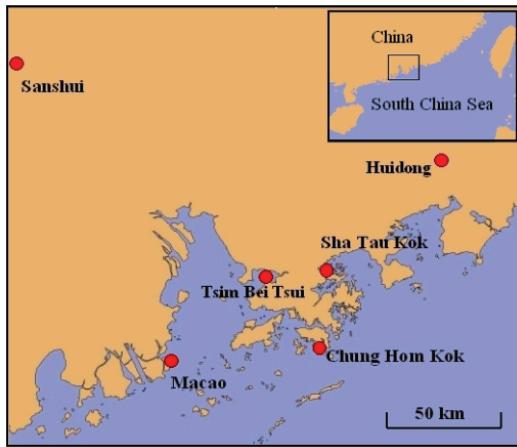
Optical flow  
tracking  
(new)

Optical flow  
tracking  
(operational)  
(TREC)

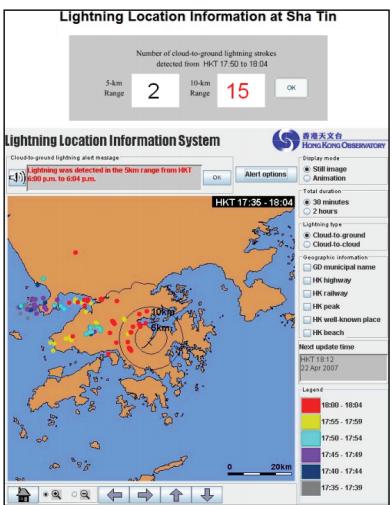
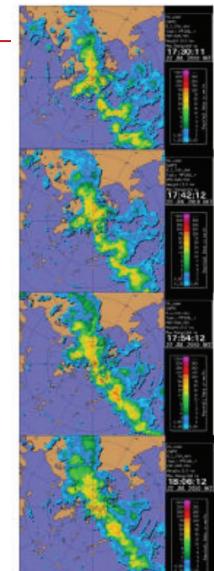
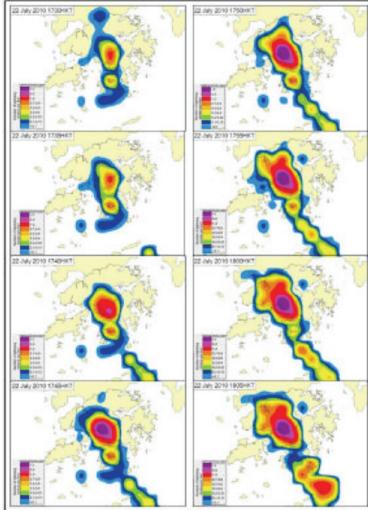


actual (moved to south of Hong Kong and dissipating)

# Use of Lightning Data

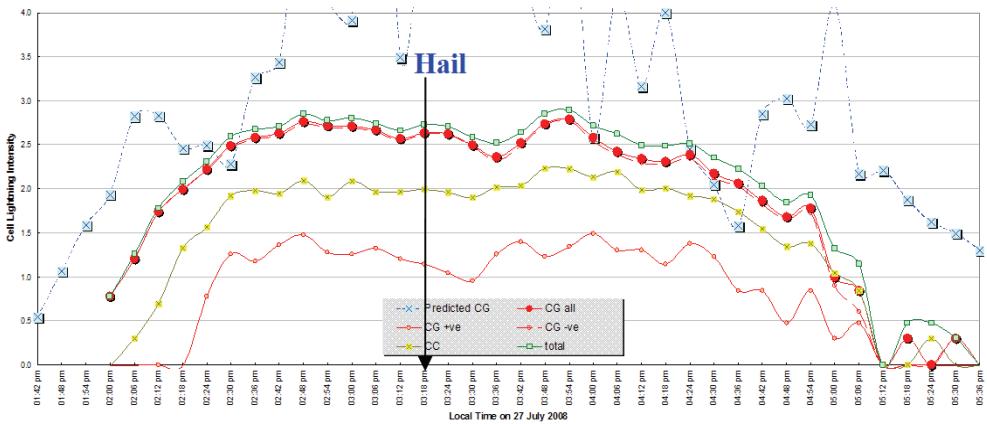


**lightning density vs radar reflectivity**



**Location-based lightning alert**

**lightning intensity change and hail**



# QPF Beyond 6 Hours?

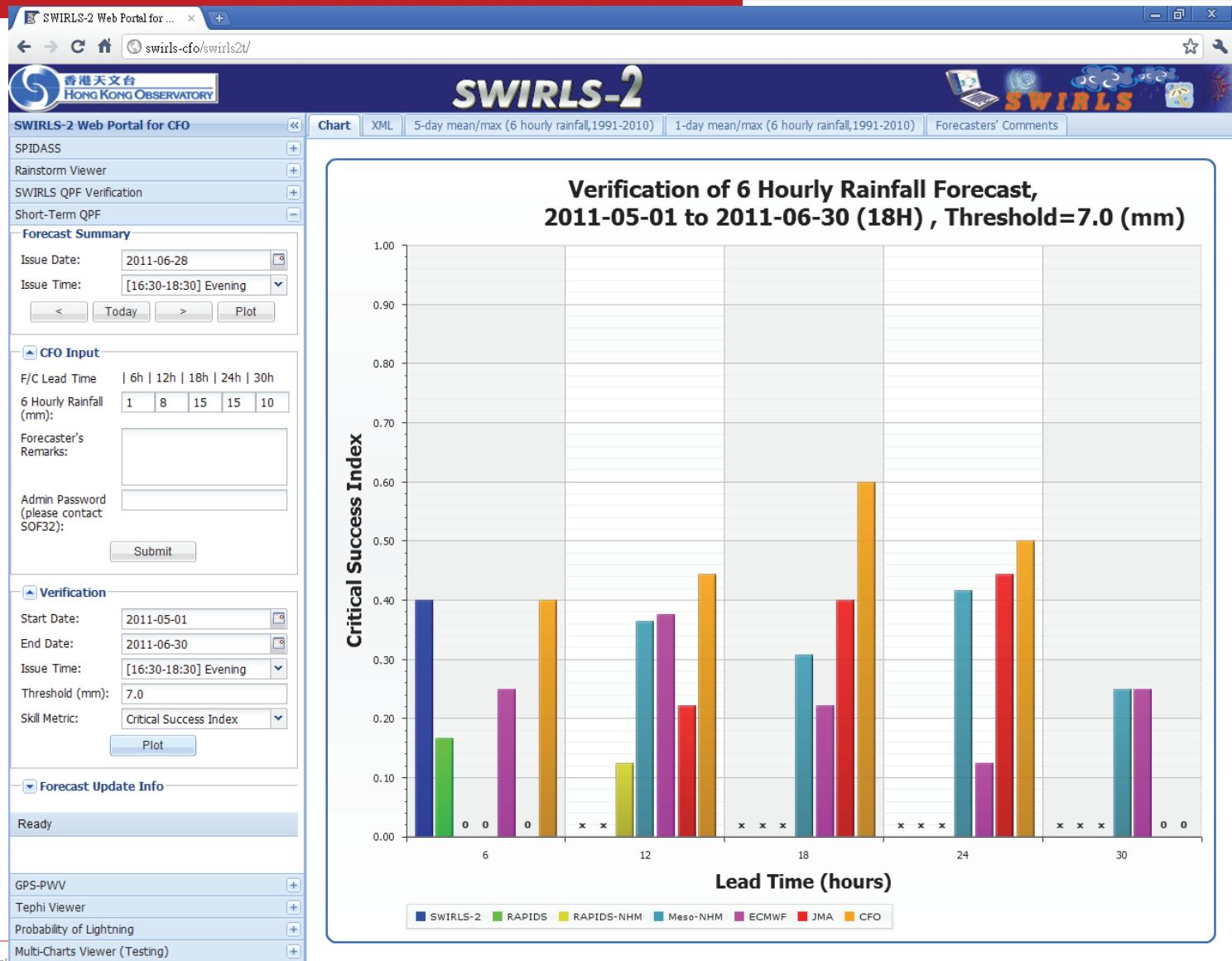
## □ 6-hourly Short-term QPF out to 30 hours:

- *updated at 6 pm*
  - will be enhanced to 4 times a day
- *including nowcast, blended, NHMs, JMA & ECMWF*
- *QPF(HK) = mean of all representative grid boxes*
- *simple average of all QPF as a 1st-guess for forecaster*

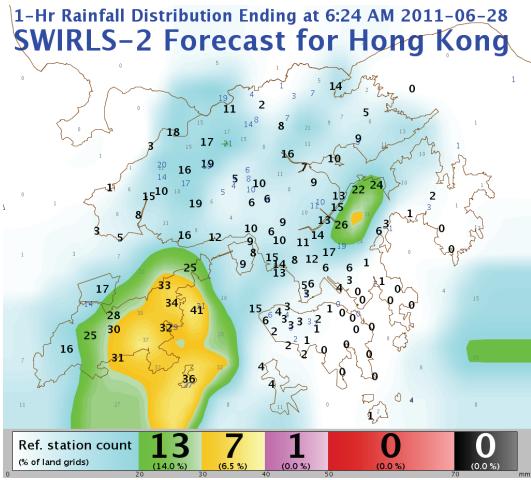
## □ Real-time verification

- *representative set of raingauge data (historical reason)*
- *both threshold-based (POD, FAR, CSI) and quantitative (mean error, RMS error, etc.)*
- *results important for further improvement*

# User Interface of 6-hr'ly QPF

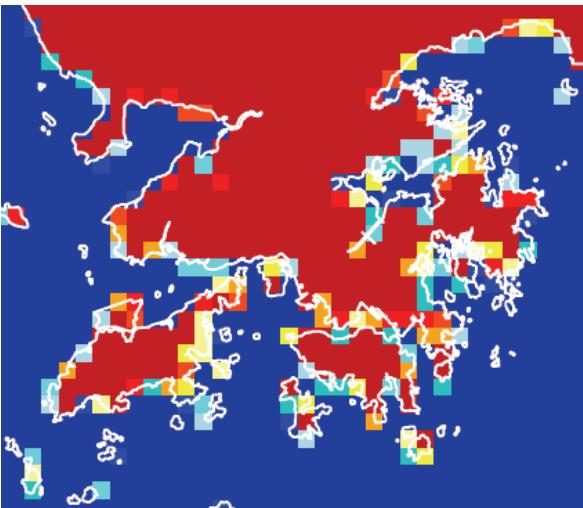


# Input Data for 6-hr'ly QPF



## SWIRLS

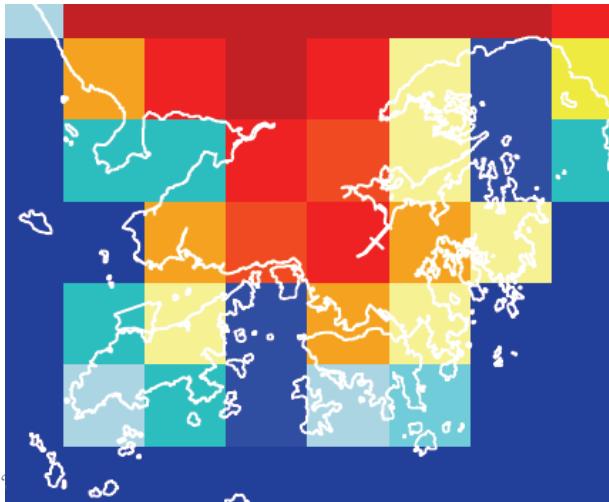
- all land boxes
- length < 1 km



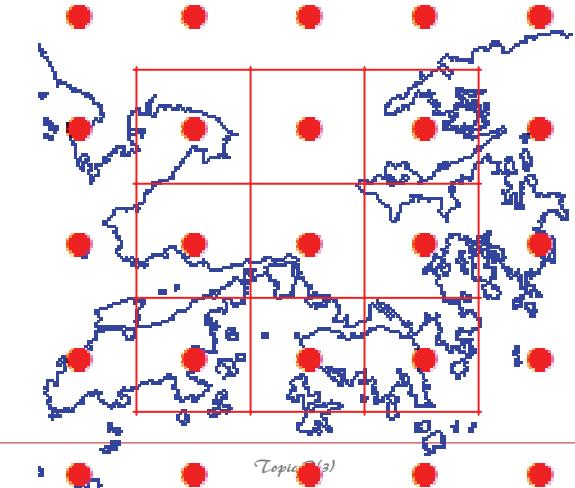
## RAPIDS & RAPIDS-NHM

- all land boxes
- length ~ 2 km

## Meso NHM - all land boxes (~ 10 km)



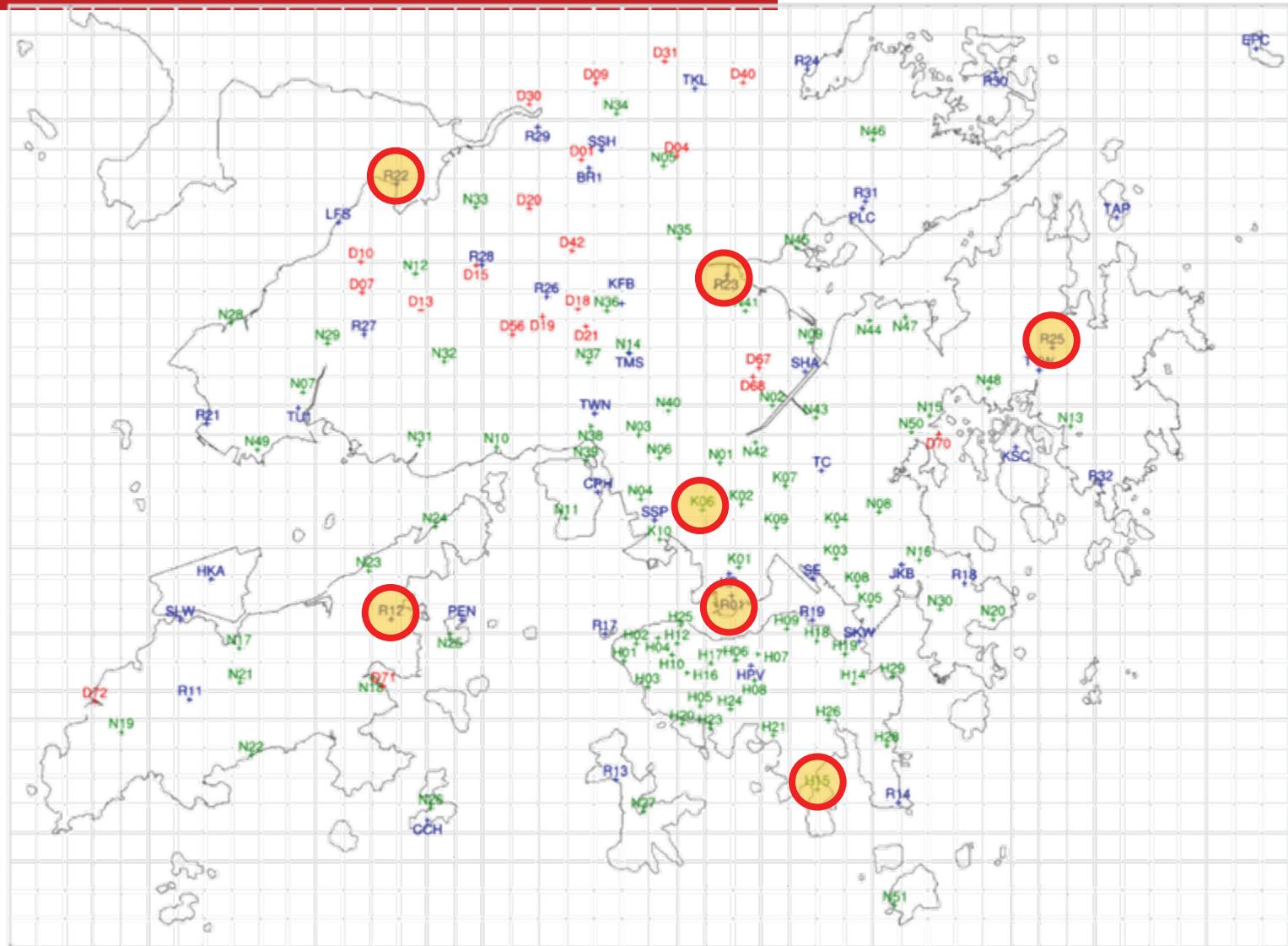
## ECMWF – center 9 boxes (0.125 deg)



## JMA – center 4 boxes (0.25 deg)

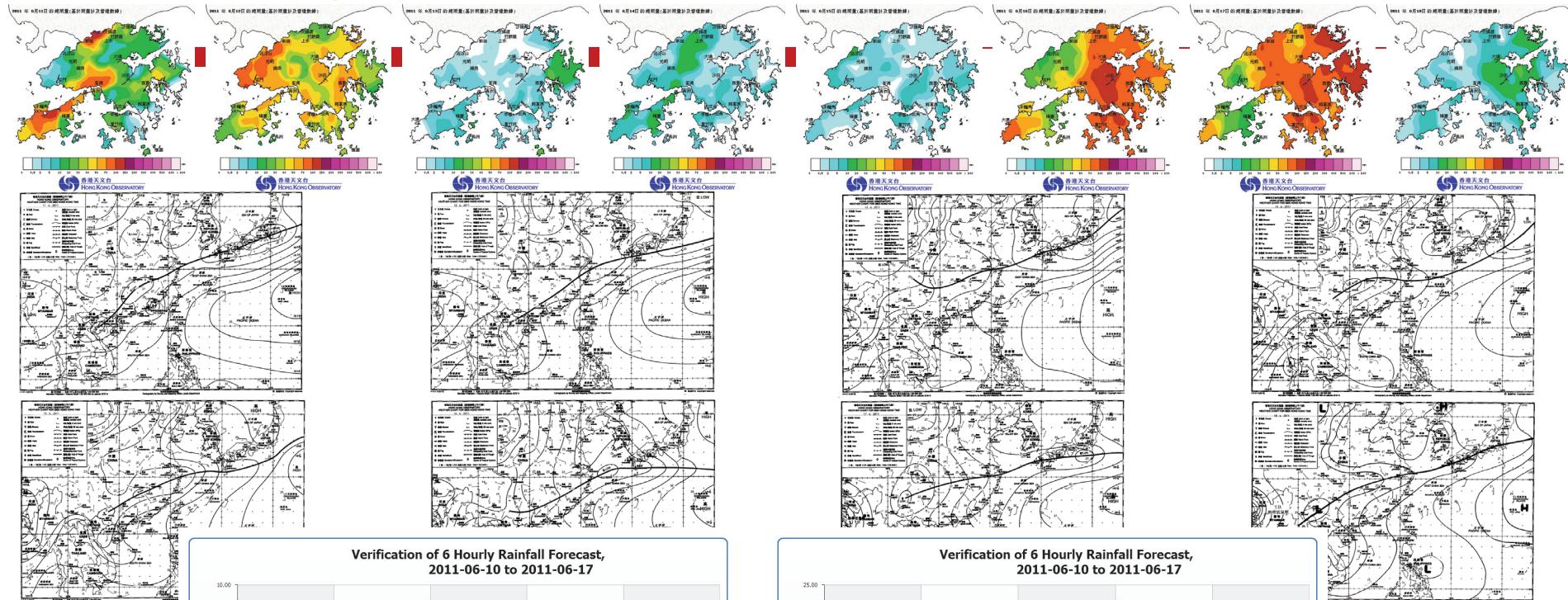


# Verification Ground Truth

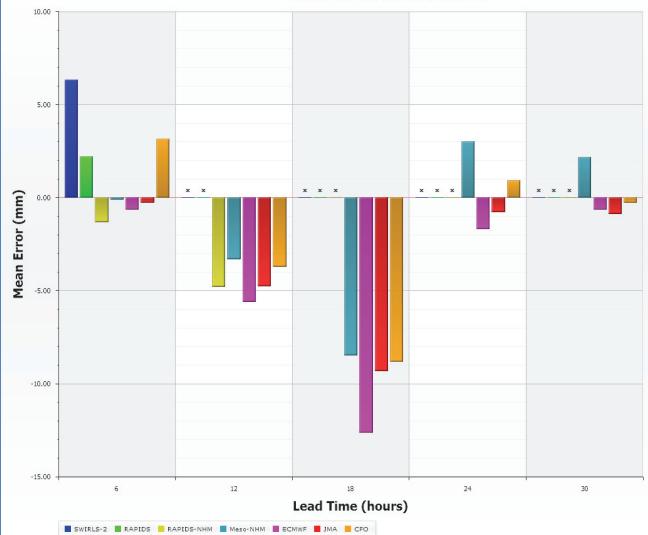


\* straight lines represent analysis grid with spacing : ~1.4 km (N-S) ; ~1.5 km (E-W)

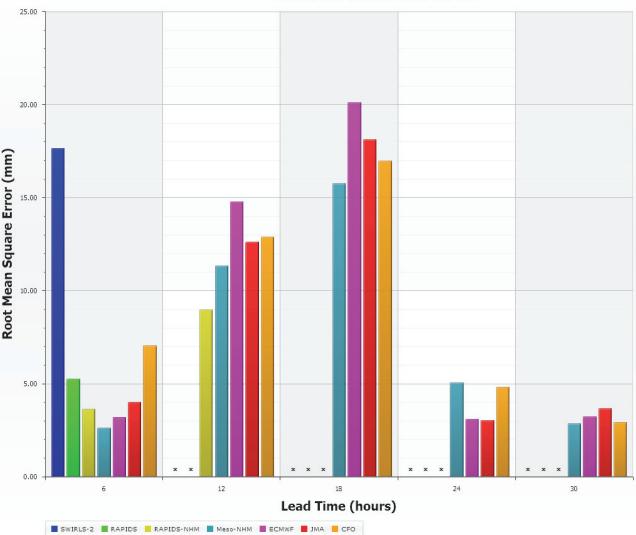
# Rainy Period (11-18 June 2011)



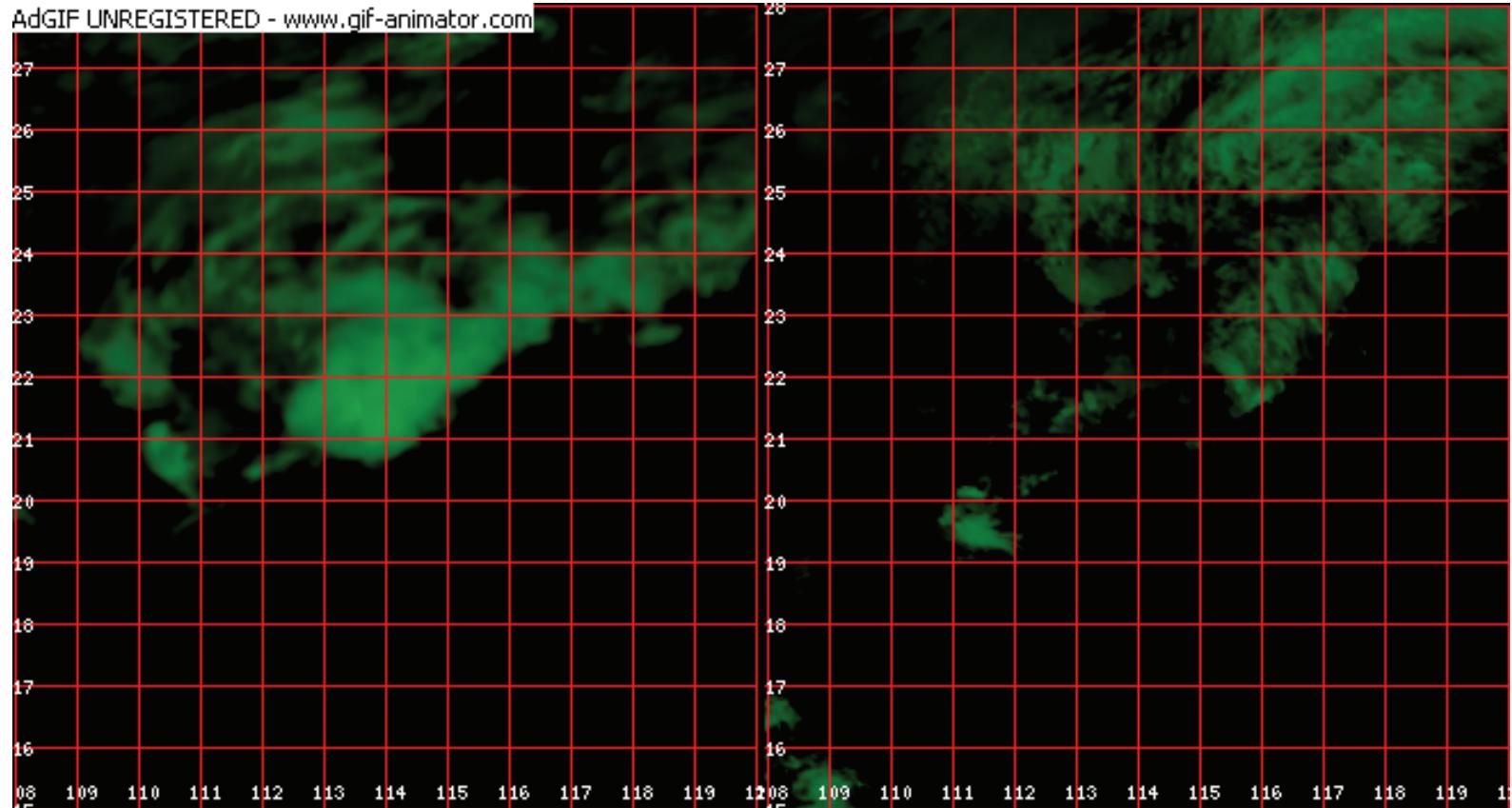
Verification of 6 Hourly Rainfall Forecast,  
2011-06-10 to 2011-06-17



Verification of 6 Hourly Rainfall Forecast,  
2011-06-10 to 2011-06-17



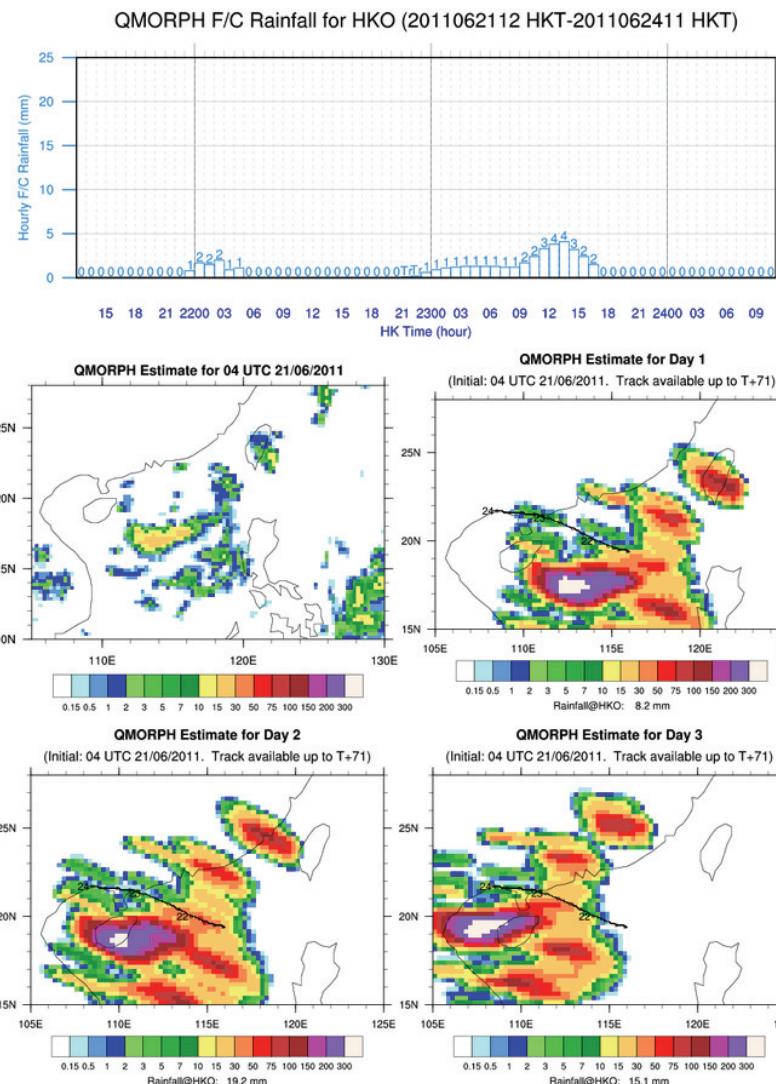
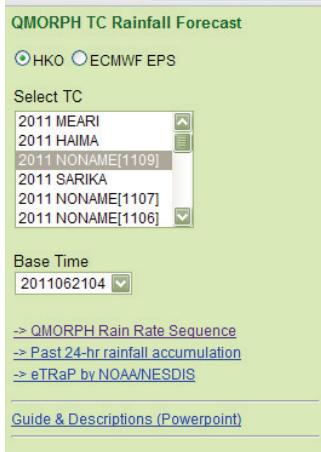
# Use of Satellite Data



- tracking & extrapolation of “convective” field derived from IR channels

# Use of Satellite Data

- QMORPH f/c rainfall
  - IR derived rainfall
  - advected along forecast TC track



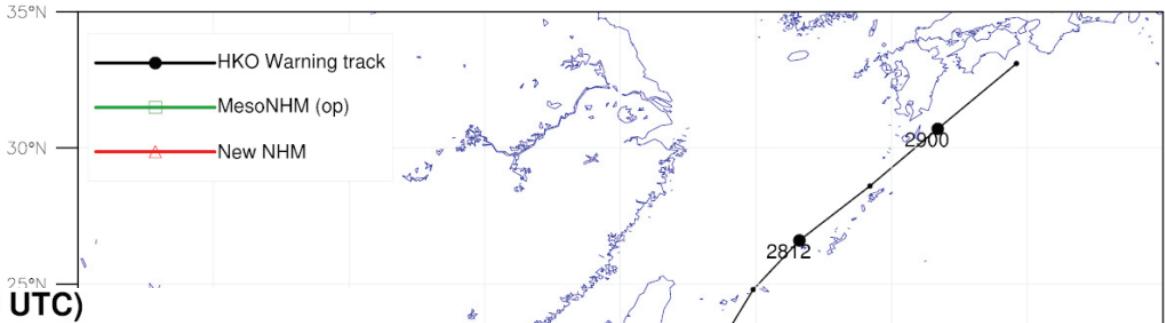
# Enhancement on Meso-NHM

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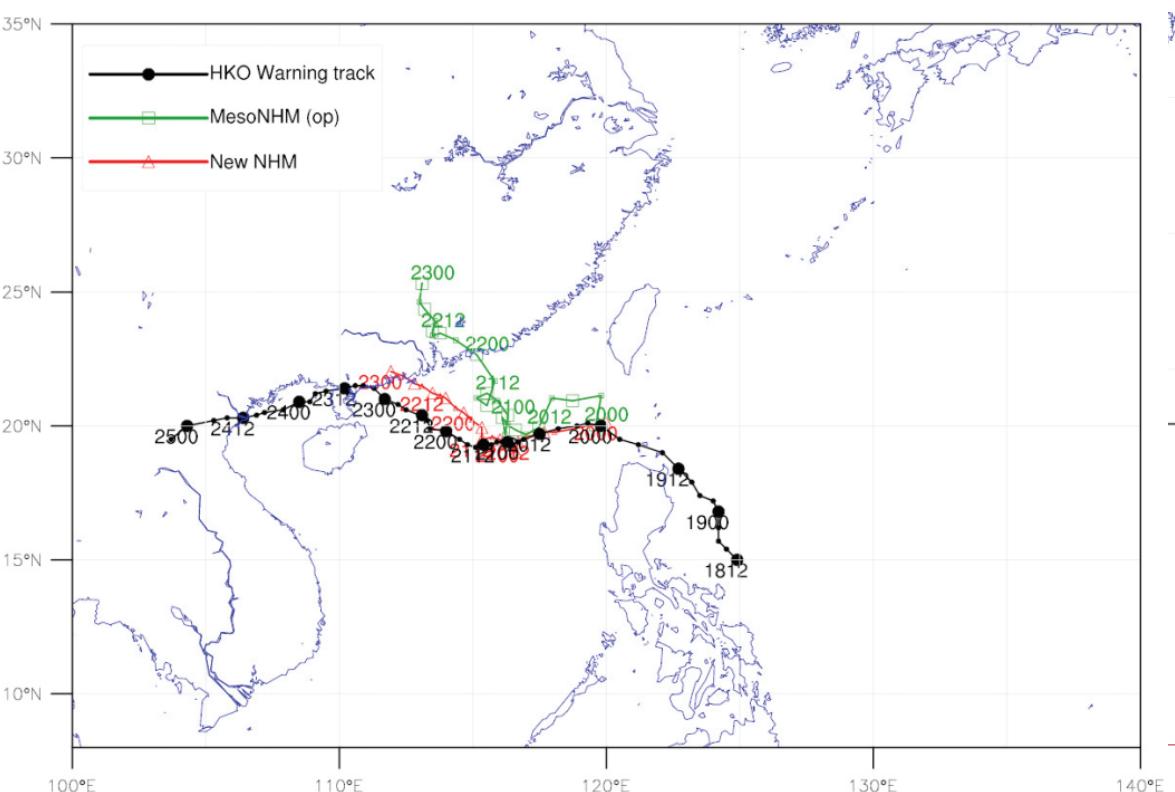
- running Meso-NHM with boundary data from ECMWF global model
  - *full resolution, more vertical levels*
  - *SST analysis, sub-surface T & moisture,*
- some improvements seen in both:
  - *TC track forecast*
  - *QPF*
  - *wind, TT and RH at low levels*
- no conclusive yet on
  - *MSLP and upper level winds*

# Meso-NHM with ECMWF - TC

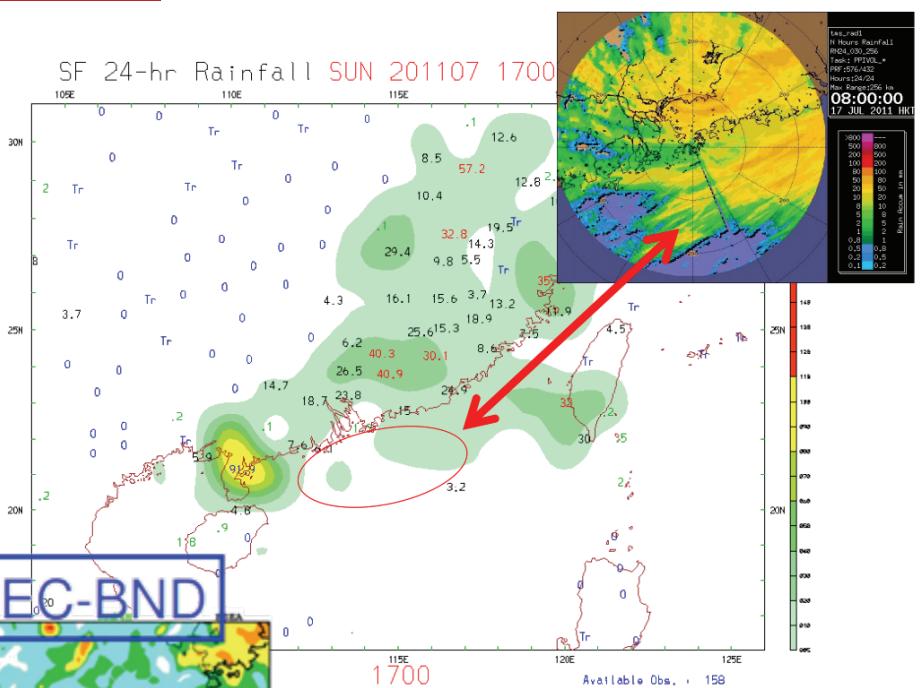
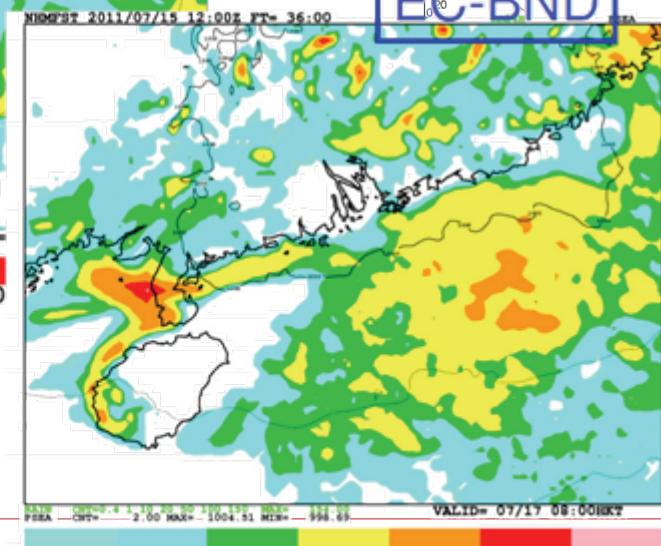
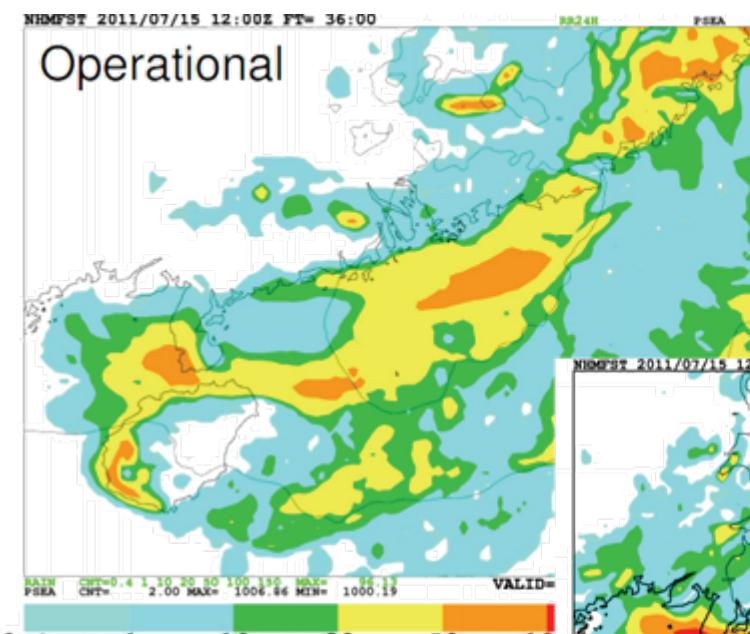
SONGDA (23-05-2011 12 UTC)



HAIMA (20-06-2011 00 UTC)



# Meso-NH/M with ECMWF-QPF



Other

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Developments  
*in the World*

# Reference Pointers

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- International Symposium on Weather Radar and Hydrology, 18-21 April 2011, Exeter, UK. (WRaH2011)
- the 3rd WMO International Conference on QPE/QPF and Hydrology, October 2010
- WMO-TLFDP, Training Workshop on Operational Tropical Cyclone Forecast, May 2010
- WMO 2nd International Workshop on Tropical Cyclone Landfall Processes (IWTCLPII), October 2009
- 41st and 42nd Session of the WMO/ESCAP Typhoon Committee, January of 2009 and 2010

# Highlights

## □ from the WRaH2011:

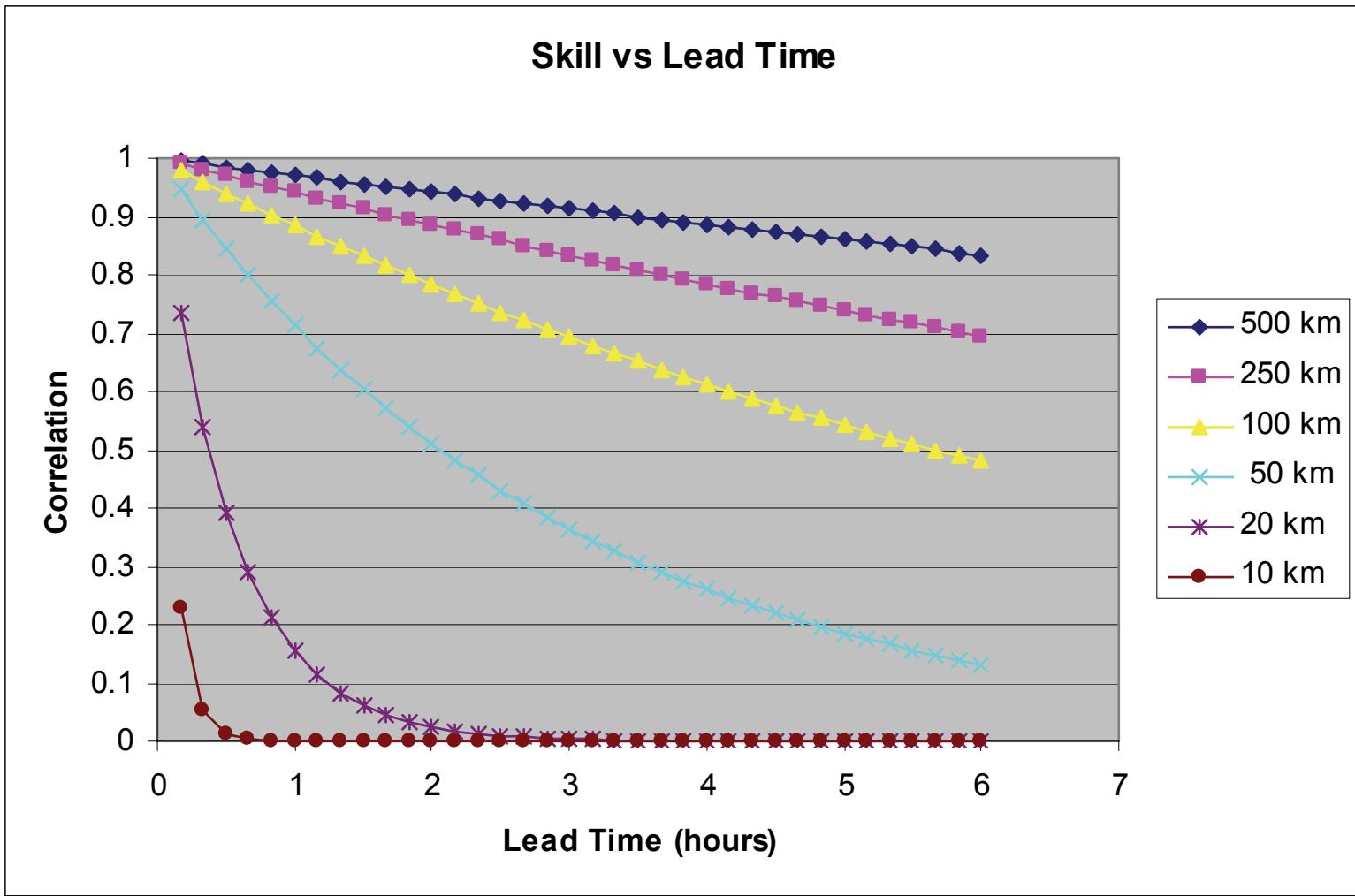
- <http://www.rmets.org/events/wrah/programme.php>
- emphasis on user applications of weather radar for flood forecasting and water management
- urban-scale QPE and QPF research using polarimetric X-band radars, phased array radars, microwave links, multi-sensor QPE, hydrometeor data assimilation and numerical simulation, urban hydrological modeling, as well as ensemble rainfall nowcasting and flood forecasting

# Highlights (cont'd)

## □ urban-scale QPE and QPF research:

- use of polarimetric X-band radars
- development economical phased array radars
- attempt to use microwave link data
- multi-sensor QPE
- hydrometeor observation, data assimilation & numerical simulation
- urban hydrological modeling
- ensemble rainfall nowcasting and flood forecasting

# Nowcast skill as a function of scale and lead time



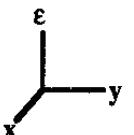
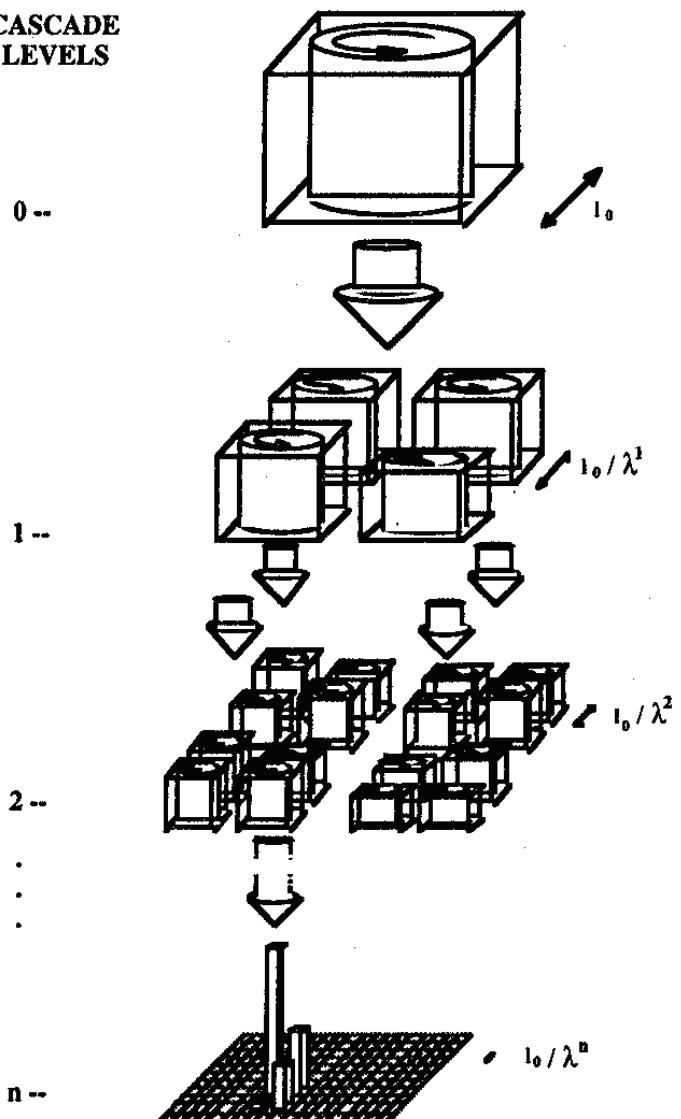
Widespread rain in Sydney

# Conceptual model for rainfall

- Rainfall usually has areas of higher intensity rainfall inside areas of lower intensity rainfall, and we get clusters of storms and not just a random pattern of storms- variability over a wide range of scales
- The lifetime of a storm increases with the size of the storm as a power law
- The simplest model is a multiplicative cascade model (used to model turbulence) for the spatial scaling and a hierarchy of AR(1) models for the Lagrangian temporal evolution so as to reproduce the dynamic scaling of the field

# Multiplicative Cascade Model for Turbulence

CASCADE  
LEVELS



multiplication by  
4 independent random  
(multiplicative)  
increments

multiplication by  
16 independent random  
(multiplicative)  
increments

Each cascade level evolves in time  
Rate of development decreases with increasing scale  
Hierarchy of AR(1) models used for temporal development

**Lovejoy et al., 1987**  
**J. Geophys. Res.**

# Ensemble Nowcasting

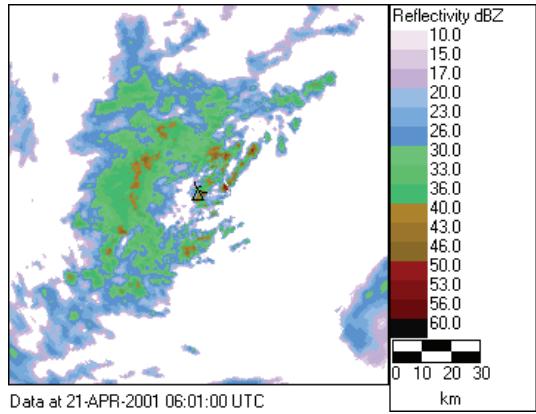
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- stochastic ensemble – ideas from STEPS
  - Short Term Ensemble Prediction System
- generate a deterministic nowcast based on radar data
- estimate the error for the nowcast over a hierarchy of spatial scales
- generate an ensemble by adding a noise component to the deterministic nowcast
  - the weight of the noise is calculated using the skill of the nowcast

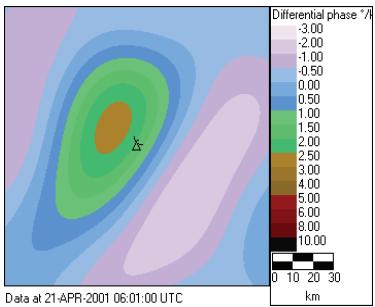
# *Short Term Ensemble Prediction System- NWP blend*

- Decompose NWP into a cascade
- Decompose the rainfall field into a cascade
- Use radar field to estimate stochastic model parameters
- Calculate the skill of the NWP at each level in the cascade using the correlation between NWP and radar
- Blend each level in the radar & NWP cascades using weights that are a function of the forecast error at that scale and lead time
- For each forecast
  - Add noise component to the deterministic blend, the weight of the noise is calculated using the skill of the blended forecast
  - Combine the cascade levels to form a forecast

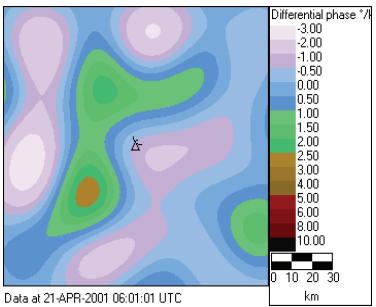
# Spectral decomposition of a rainfall field



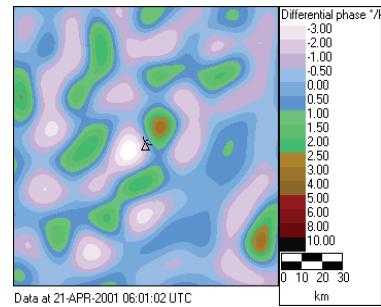
**128-256-512 km**



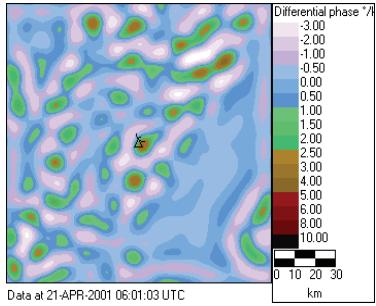
**64-128-256 km**



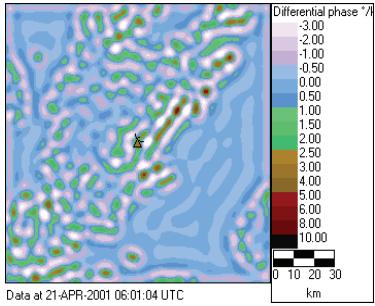
**32-64-128 km**



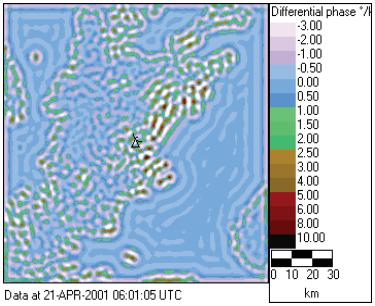
**16-32-64 km**



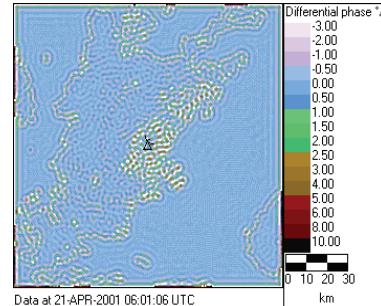
**8-16-32 km**



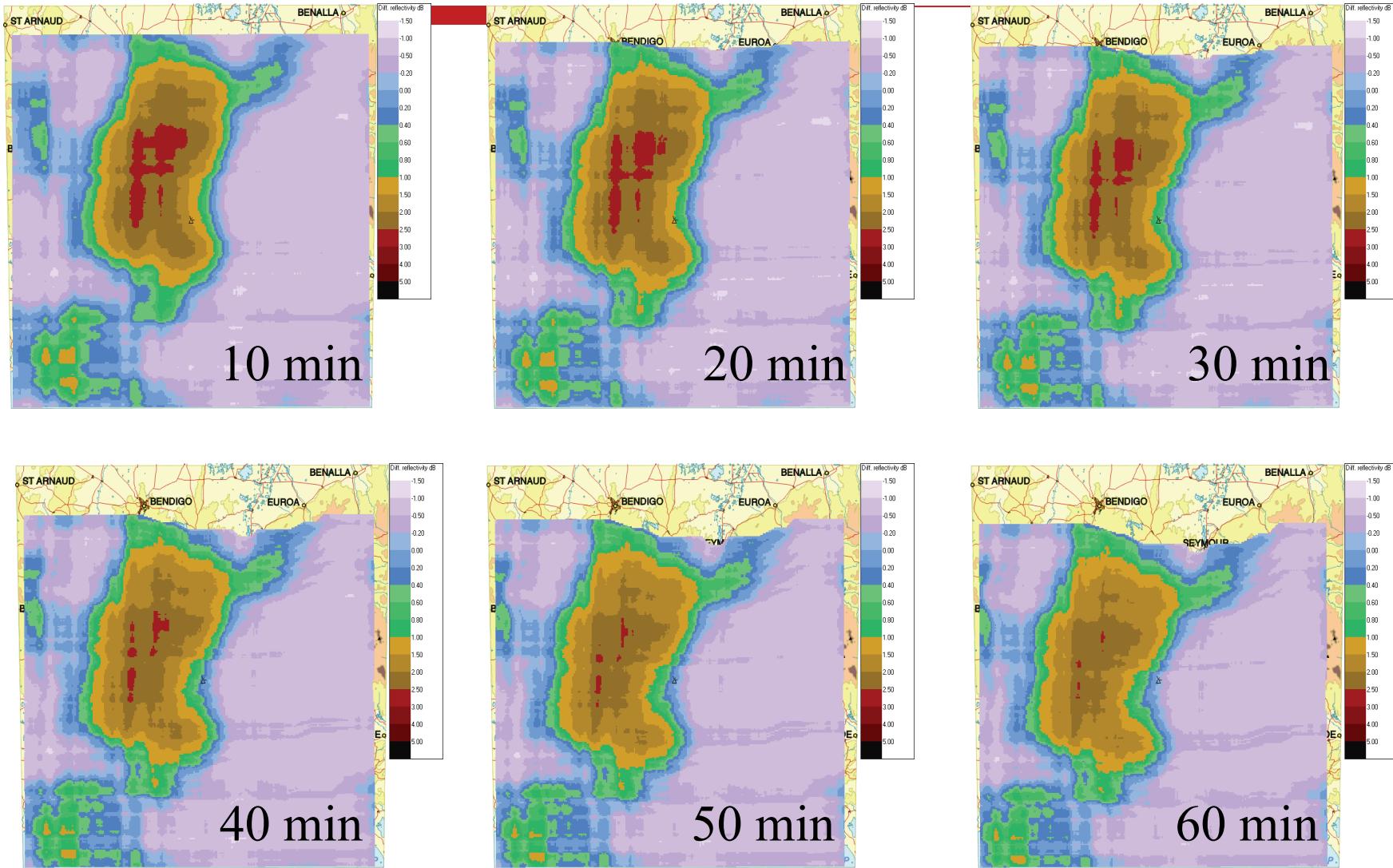
**4-8-16 km**



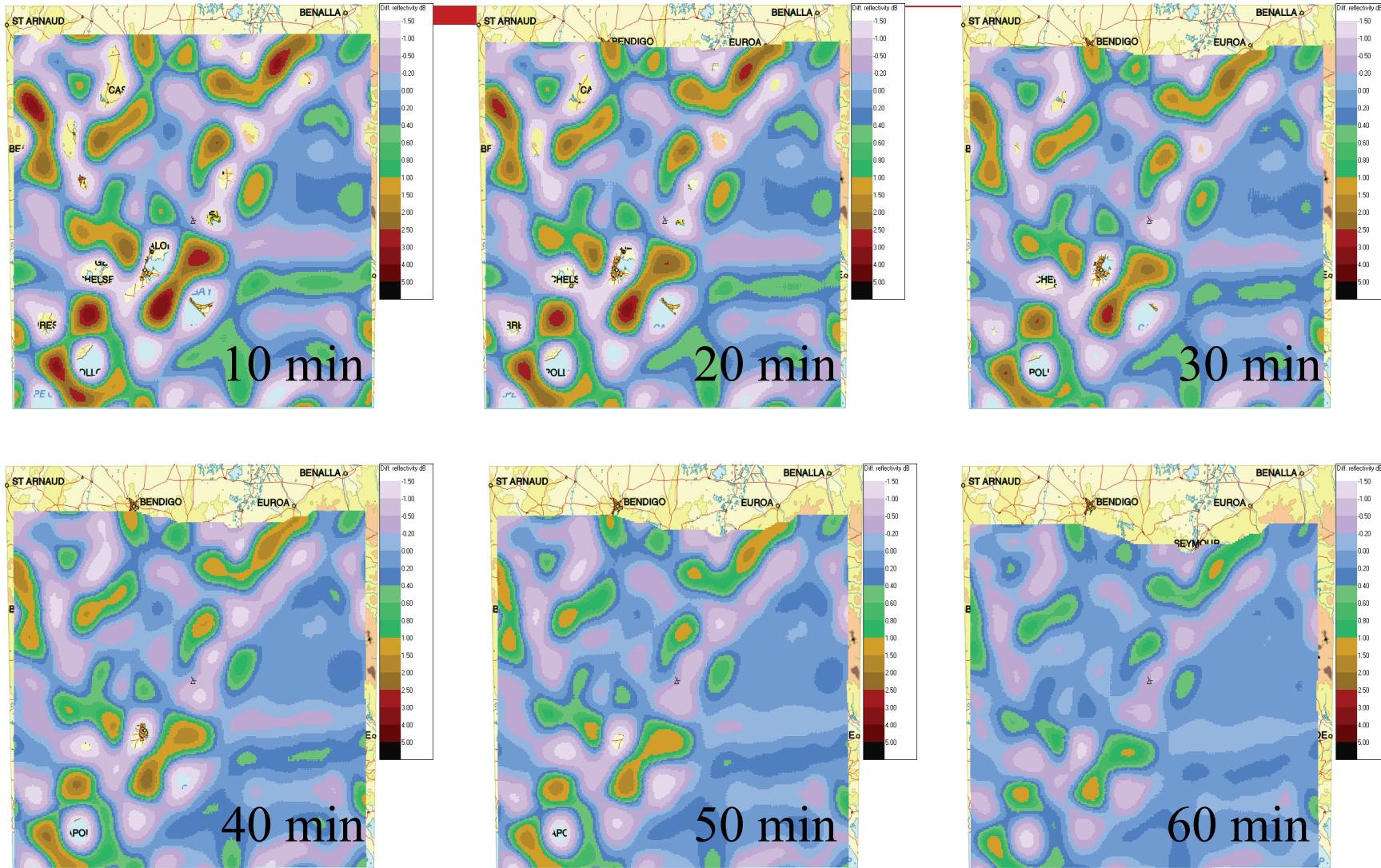
**2-4-8 km**



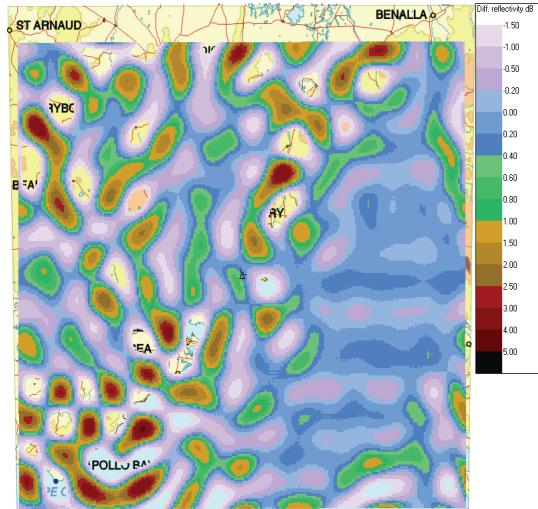
# 256 - 128 km Nowcast Fields



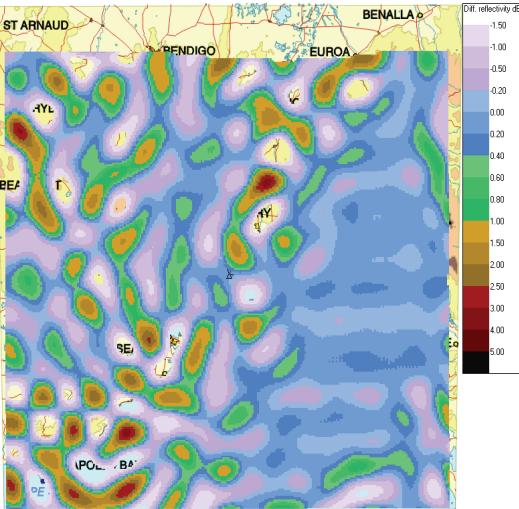
# 128 - 64 km Nowcast Fields



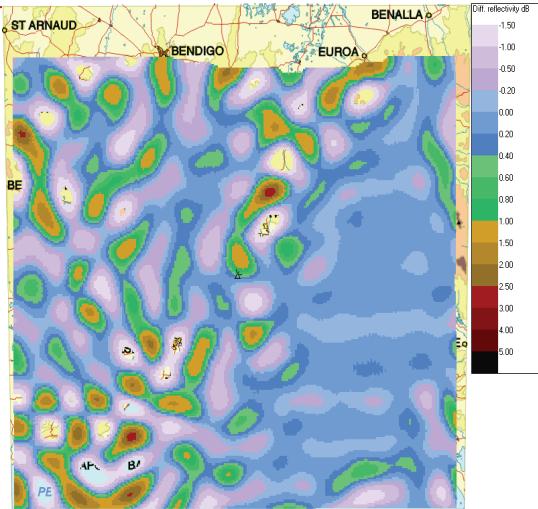
# 64 - 32 km Nowcast Fields



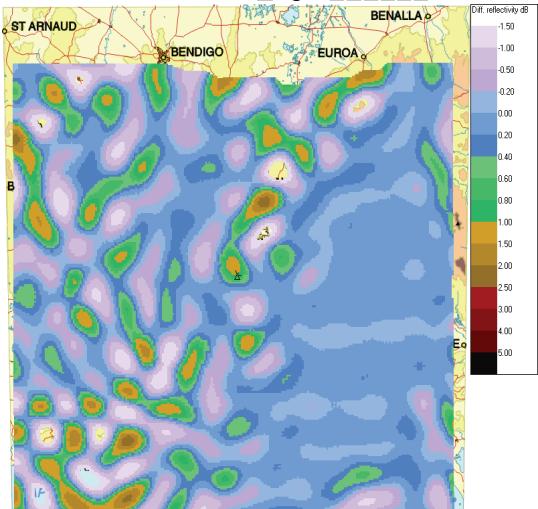
10 min



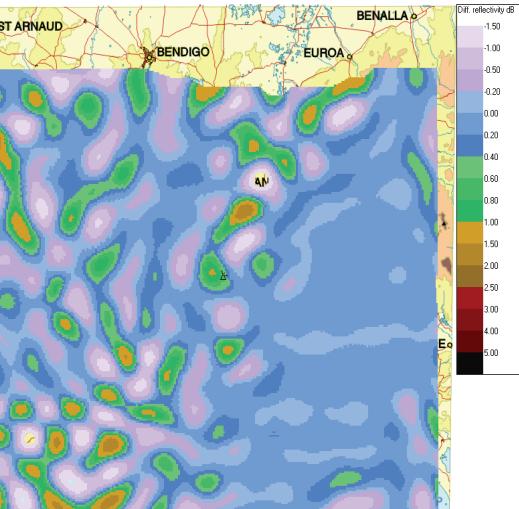
20 min



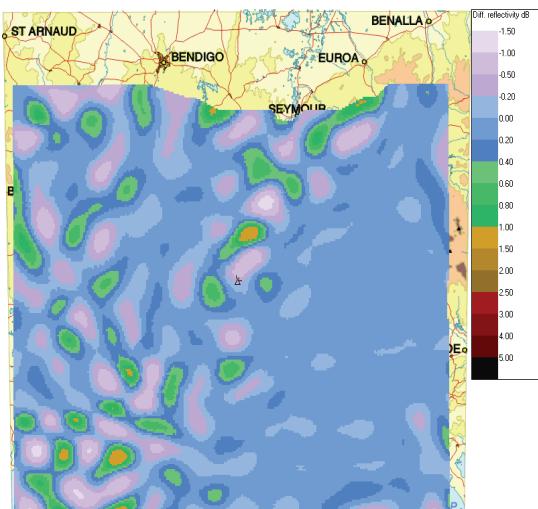
30 min



40 min

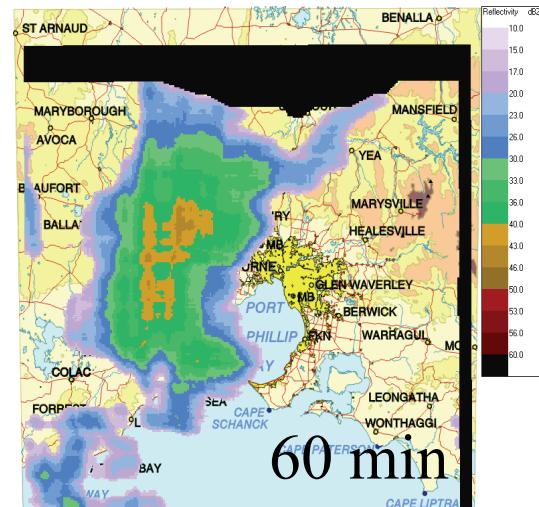
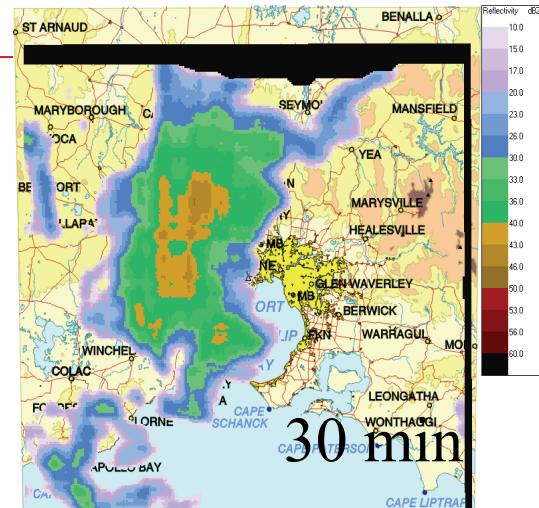
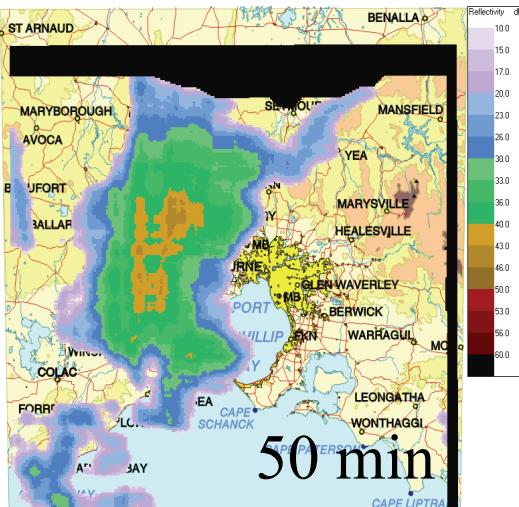
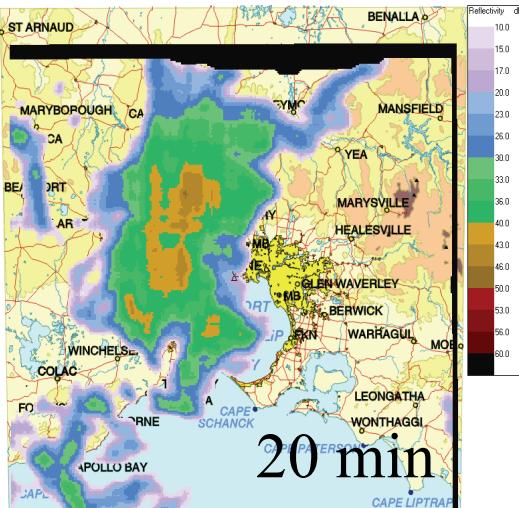
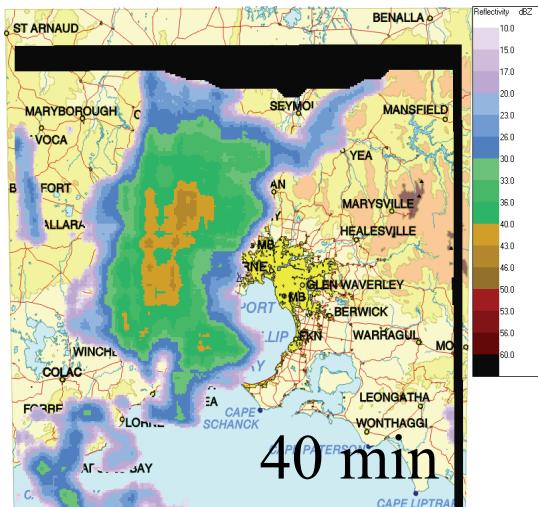
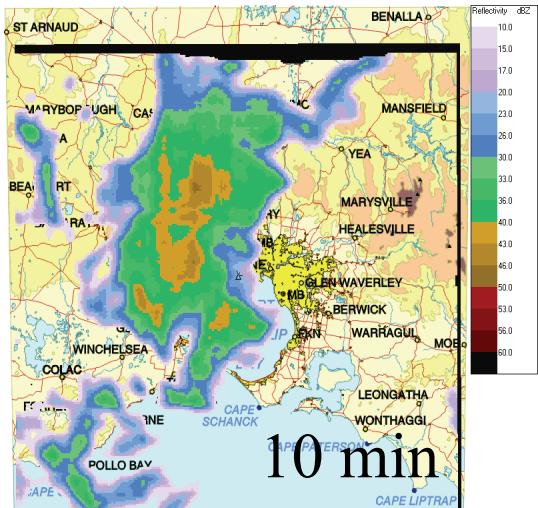


50 min

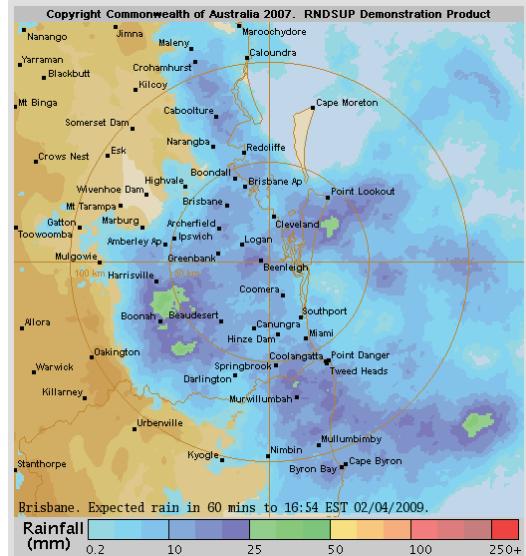


60 min

# Nowcasts



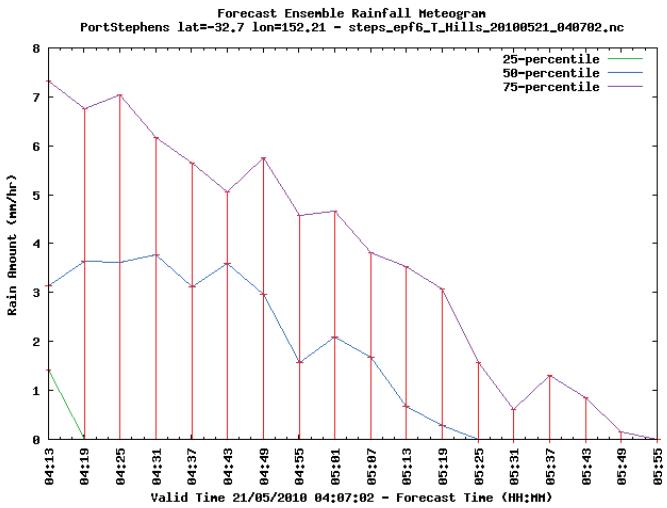
# Rainfall Forecasts: 0 – 90 minutes



60 min accumulation



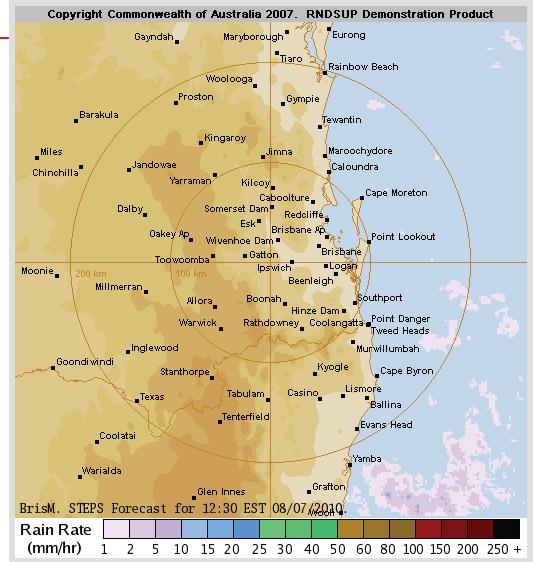
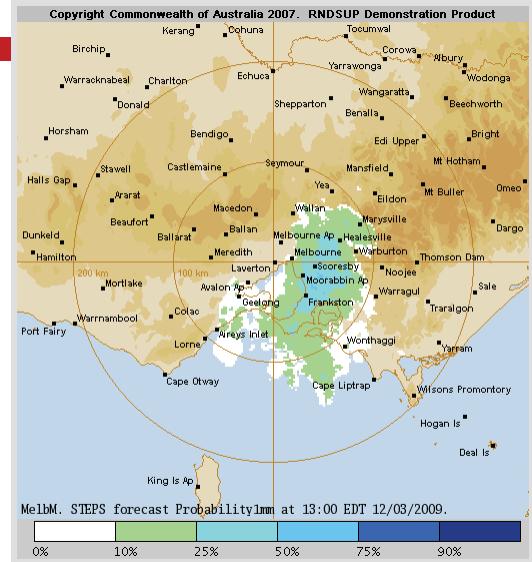
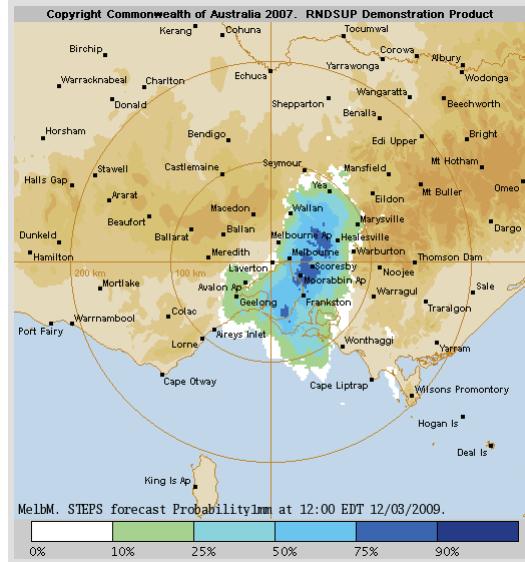
Probability of rain &gt; 50 mm



Forecast time series at a point with uncertainty shown

- 4 major cities, 1 km & 6 min resolution, 250 km domain
- 3 Regional forecasts, 2 km & 10 min resolution, 500 km domain
- 30 member ensemble updated every 6,10 minutes
- 30, 60, 90 min accumulations of ensemble mean (expected rain)
- Probability that rain accumulation will exceed 1,2,5,10,20,50 mm in next 60 minutes
- 2000 images per hour

# Rainfall forecasts: 1 – 6 hours

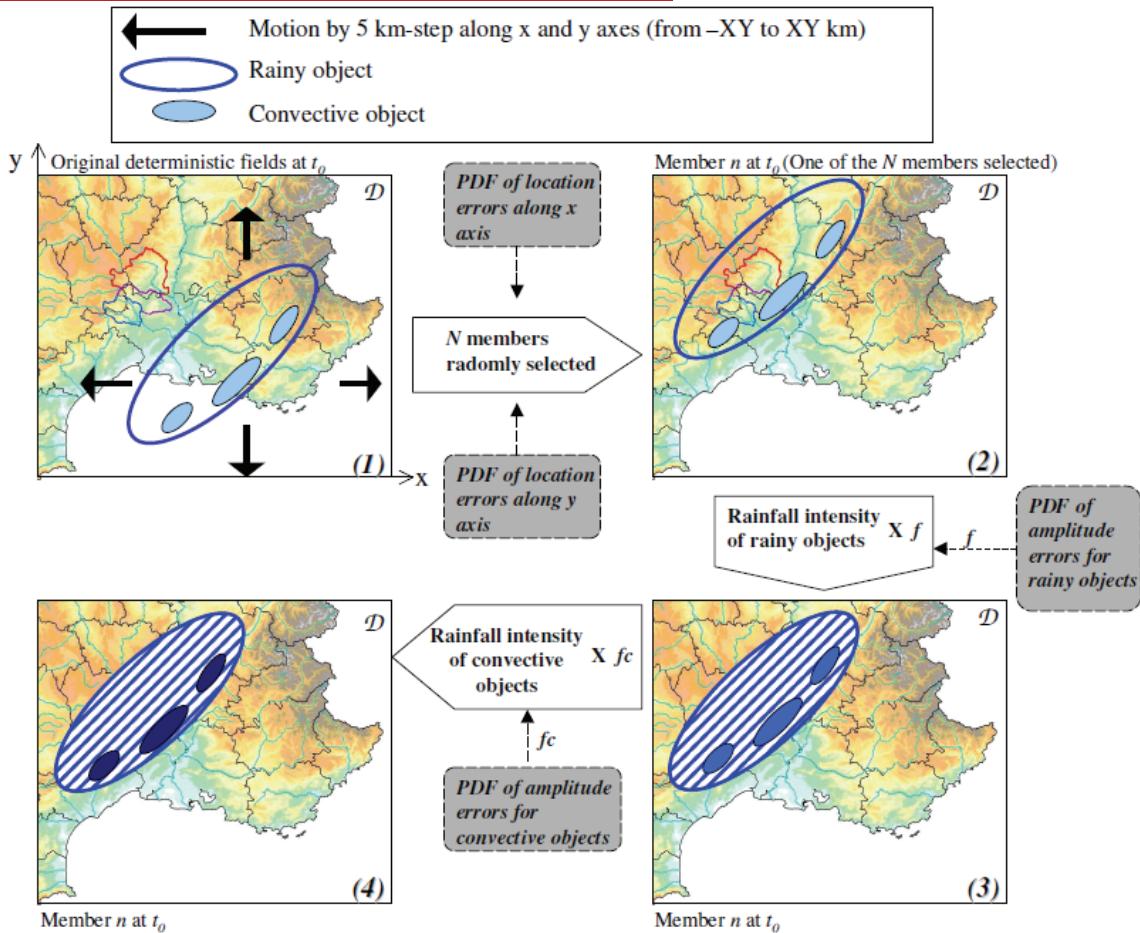


Probability of rain > 1 mm for 2 & 3 hour lead times, Melbourne

Rainfall intensity forecast, 150 min lead time, Brisbane

- Melbourne, Sydney, Brisbane – 500 km domain, 2 km & 10 min resolution**
- 30 member ensemble updated every hour**
- 10-min forecasts of rainfall intensity out to 6 hours**
- Probability products for hourly accumulations for next 6 hours**

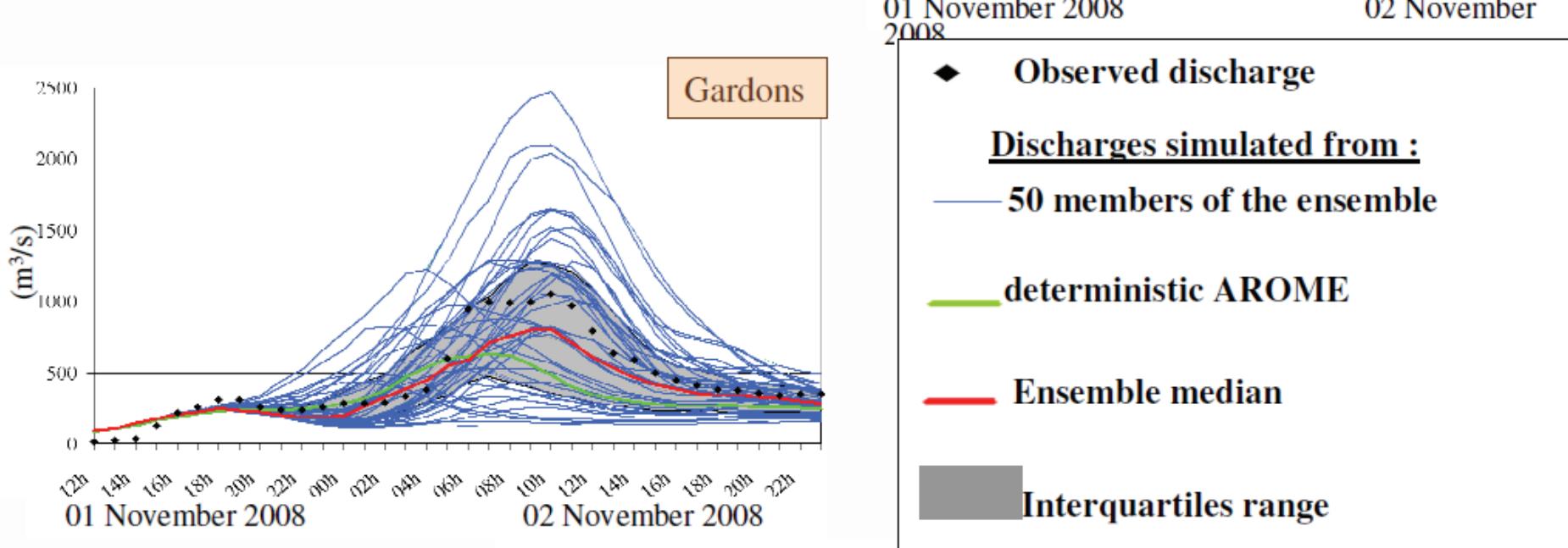
# Flash Flood Ensemble Forecasting



Principle of the perturbation generation method at time  $t_0$ .

■ based on NWP QPF error statistics (intensity & location)

# Flash Flood Ensemble Forecasting



- Vincendon et al. 2011
  - <http://www.nat-hazards-earth-syst-sci.net/11/1529/2011/nhess-11-1529-2011.html>

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