香港天文台
HONG KONG OBSERVATORY

NOWCASTING SYSTEMS AND SERVICES IN HONG KONG

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3rd WMO/WWRP International Symposium on Nowcasting and Very Short Range Forecasting

Rio de Janeiro 6-10 August 2012

- Nowcasts are precise in weather element, time and space!
- Extreme events!
- “Call to Action!”

- Stakeholders:
  - *General public*
  - *Government departments*
  - *Transportation*
  - *Public utilities*
  - *…*

Decision-making

0-6 hours ahead is a kind of norm

LOCAL PUBLIC WEATHER FORECAST AND WARNING SERVICES ON HIGH IMPACT WEATHER

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Tropical Cyclone

TC within 800 km of HK

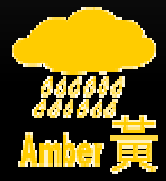
Winds blowing 41-62 km/hr within 12 hours over Harbour

Winds blowing 63-117 km/hr at half ref. stn

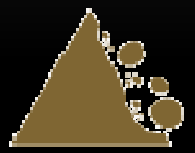
Increasing gale or storm force winds

Winds blowing 118 km/hr or above

Rainstorm & related

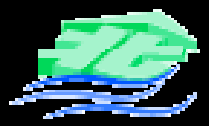


≥ 30 mm/hr



Landslip

≥ 50 mm/hr



Special Announcement of Flooding

≥ 70 mm/hr

Strong Monsoon

Thunderstorm Warning

- Rainstorm Warnings
  - *intense, widespread & persistent heavy rain*
- Landslip Warning
  - *resulted from prolonged rainfall*
  - *will be issued if 15 or more major landslides is expected*
- Special Announcement of Flooding
  - *specific for low-lying areas in northern part of Hong Kong*
- Thunderstorm warnings
  - *with special reports on severe weather of high gust, hail*
- Tropical Cyclone Warnings
  - *No.1, 3, 8, 9, 10 for standby, strong winds, gales, increasing gales & hurricane force*
- Strong Monsoon Signal
  - *to warn high winds associated with monsoon*

HKO NOWCASTING SYSTEMS

- For Public Weather and Warning Services, including supporting Government departments – SWIRLS
- For Aviation Community – ATLAS (Airport Thunderstorm and Lightning System) and ATNS (Aviation Thunderstorm Nowcasting System)
- For Public Utility - ENS (Ensemble Nowcasting System) on lightning

For latest SWIRLS development, please tune on to Mr Linus HY Yeung

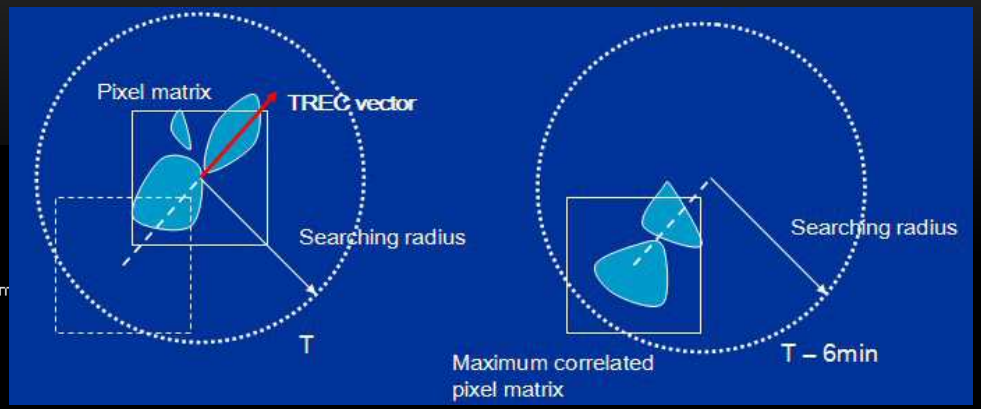
- "Recent Developments and Applications of the SWIRLS Nowcasting System in Hong Kong"
- "Application of Optical-Flow Technique to Significant Convection Nowcast for Terminal Areas in Hong Kong"

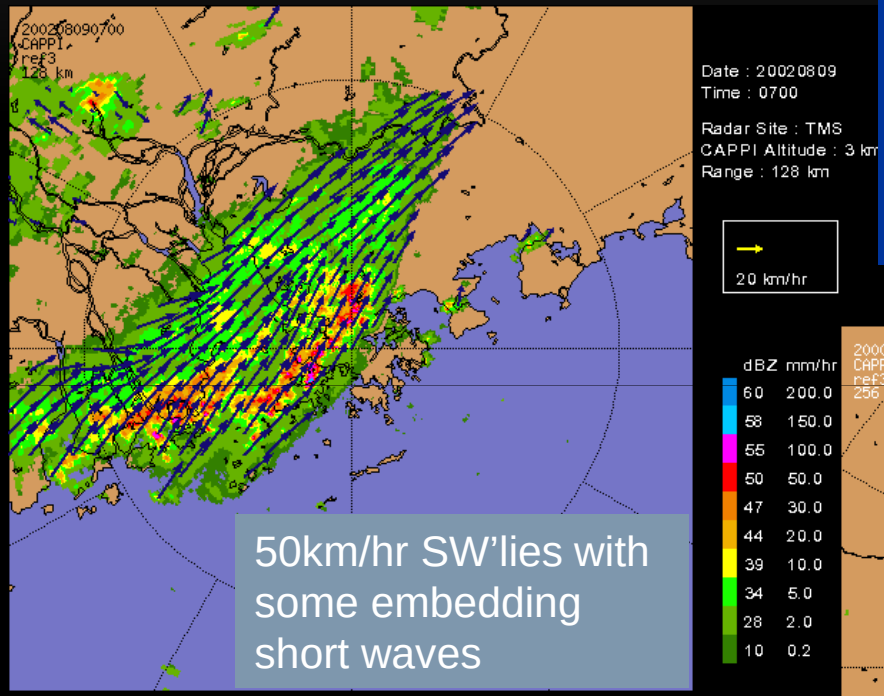
RADAR ECHO TRACKING TECHNIQUES

- Differential Tracking component
  - TREC (Tracking Radar Echoes by Correlation) – Legacy method
    - Capture small scale movement, including divergence and circulation
    - Scale of movement depending on the box size
    - BUT: overlook large scale (System) movement
- Object-based Tracking component
    - Capture well the system movement
    - BUT: cannot maintain rotating system's structure
    - BUT: system merge and split tracing and forecasting problems
- Integral Tracking component
  - MOVA (Multiscale Optical flow by Variational Analysis) and ROVER (Real-time Optical Flow by Variational methods for Echoes of Radar)
    - Various scales treated
    - Capture better large scale (system) movement in comparison with TREC

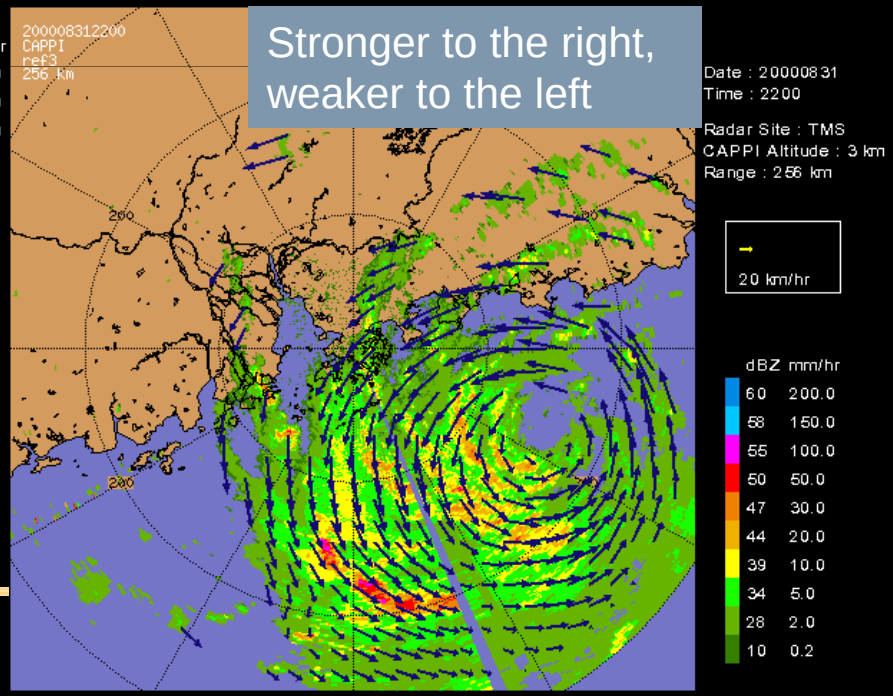
SWIRLS is a hybrid system

TREC (Tracking Radar Echoes by Correlation)





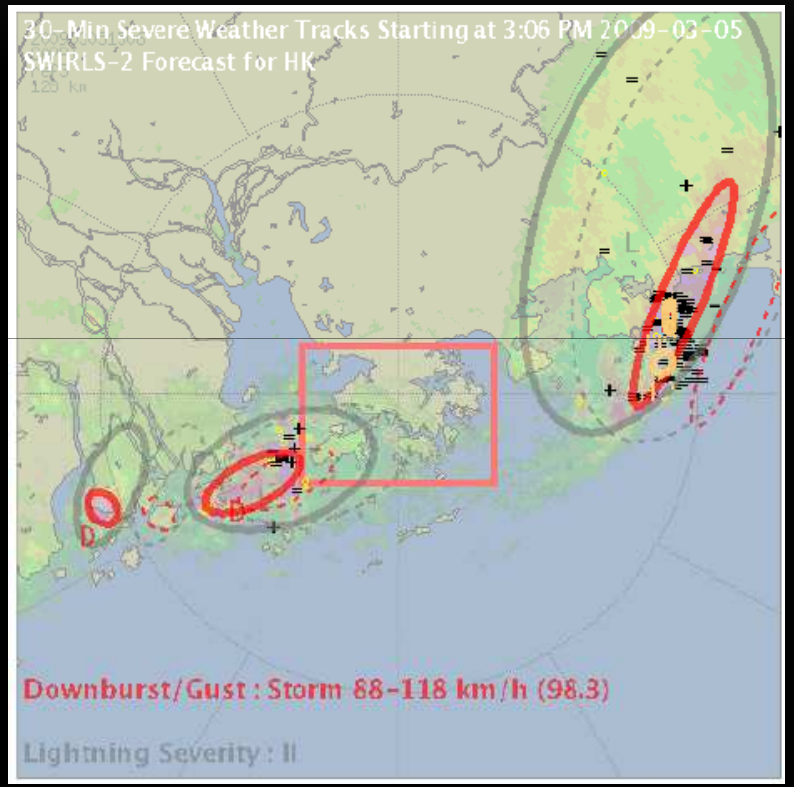
3 km TREC wind of an intense rainstorm



3 km TREC wind of a tropical cyclone

SWIRLS2 PRODUCTS

Product Type	*Forecast Element*
Severe weather	**lightning, downburst/gust hail**



SPIDASS – "AT-A-GLANCE" WITH RVS

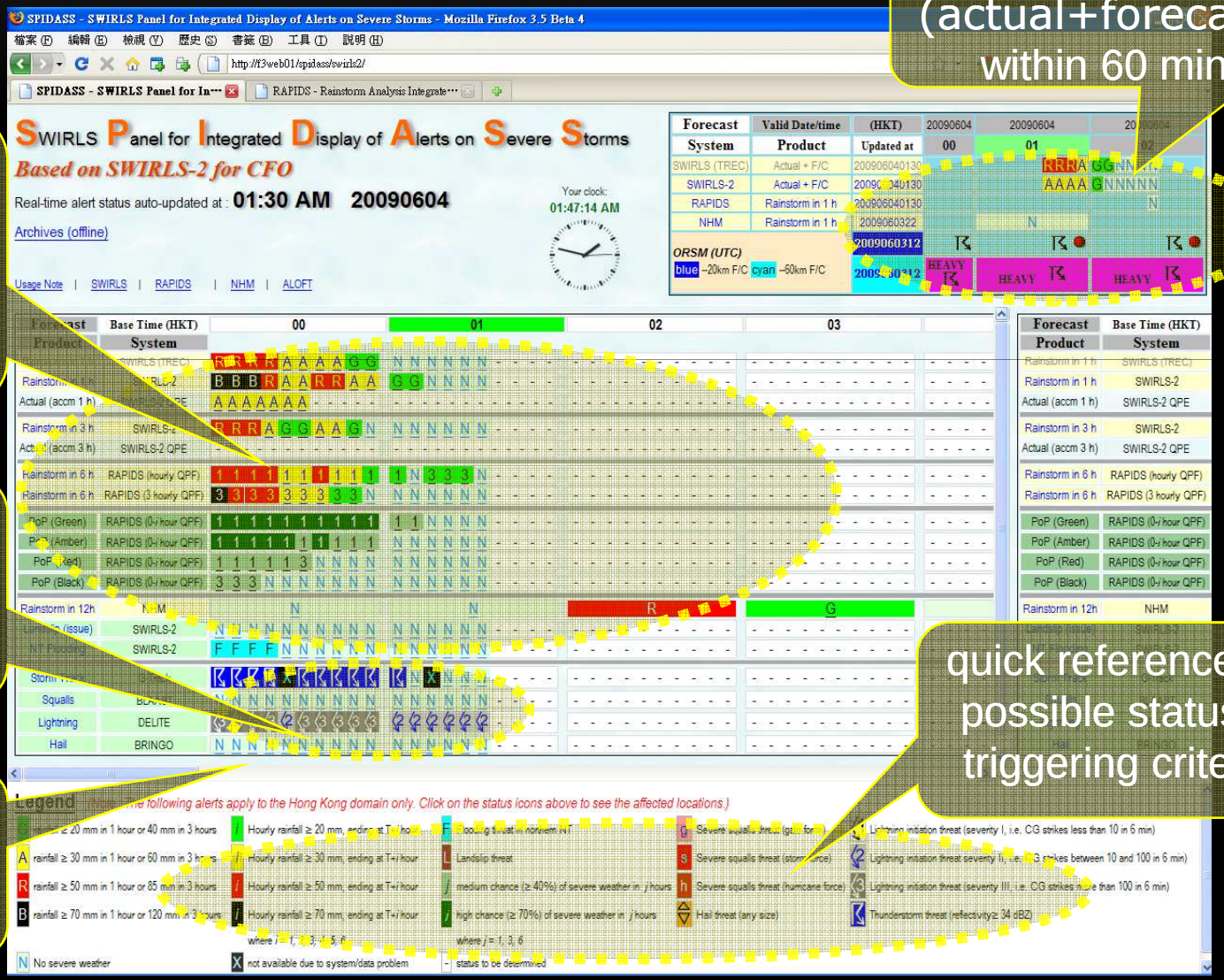
Rainstorm-related alerts:
- 1-6 hours
- auto-updated every 6 min

Severe weather alerts associated with thunderstorms

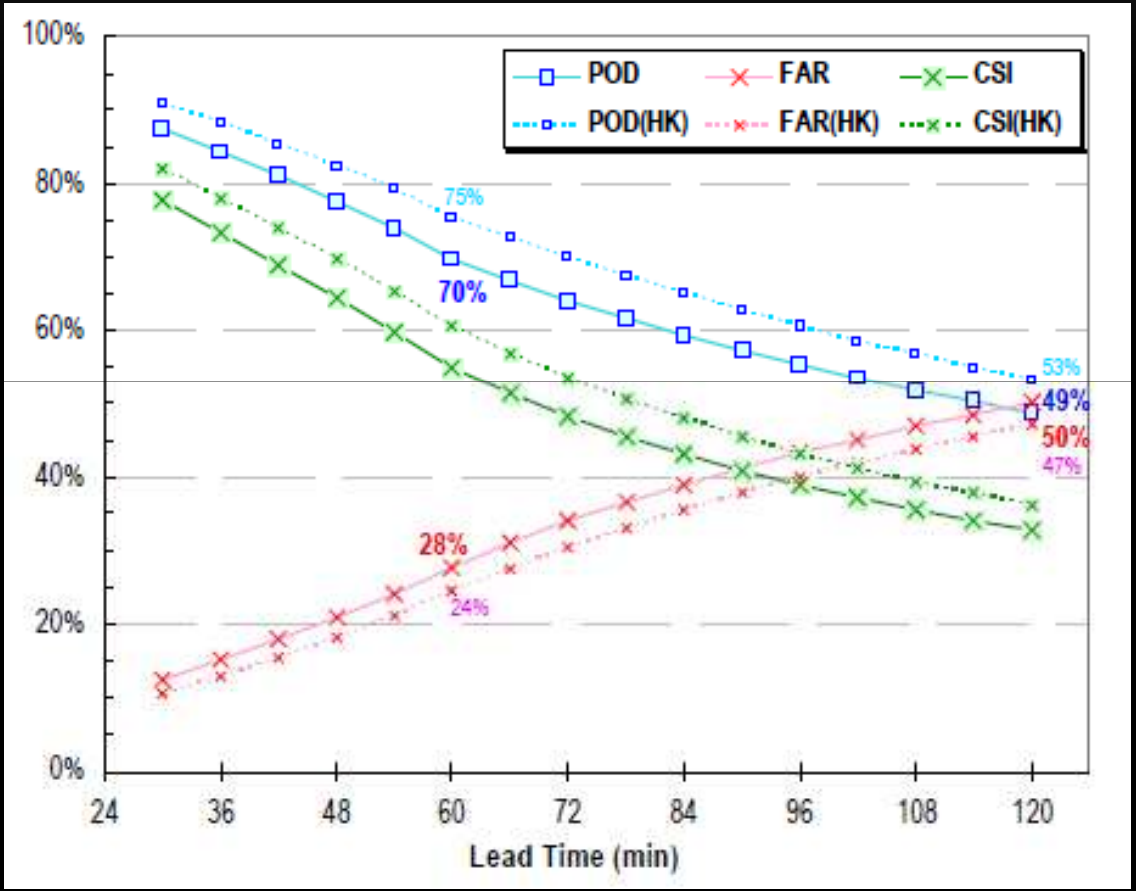
Severe weather map available on mouse click

Rainstorm alerts (actual+forecast) within 60 min

quick reference on possible status & triggering criteria



PERFORMANCE

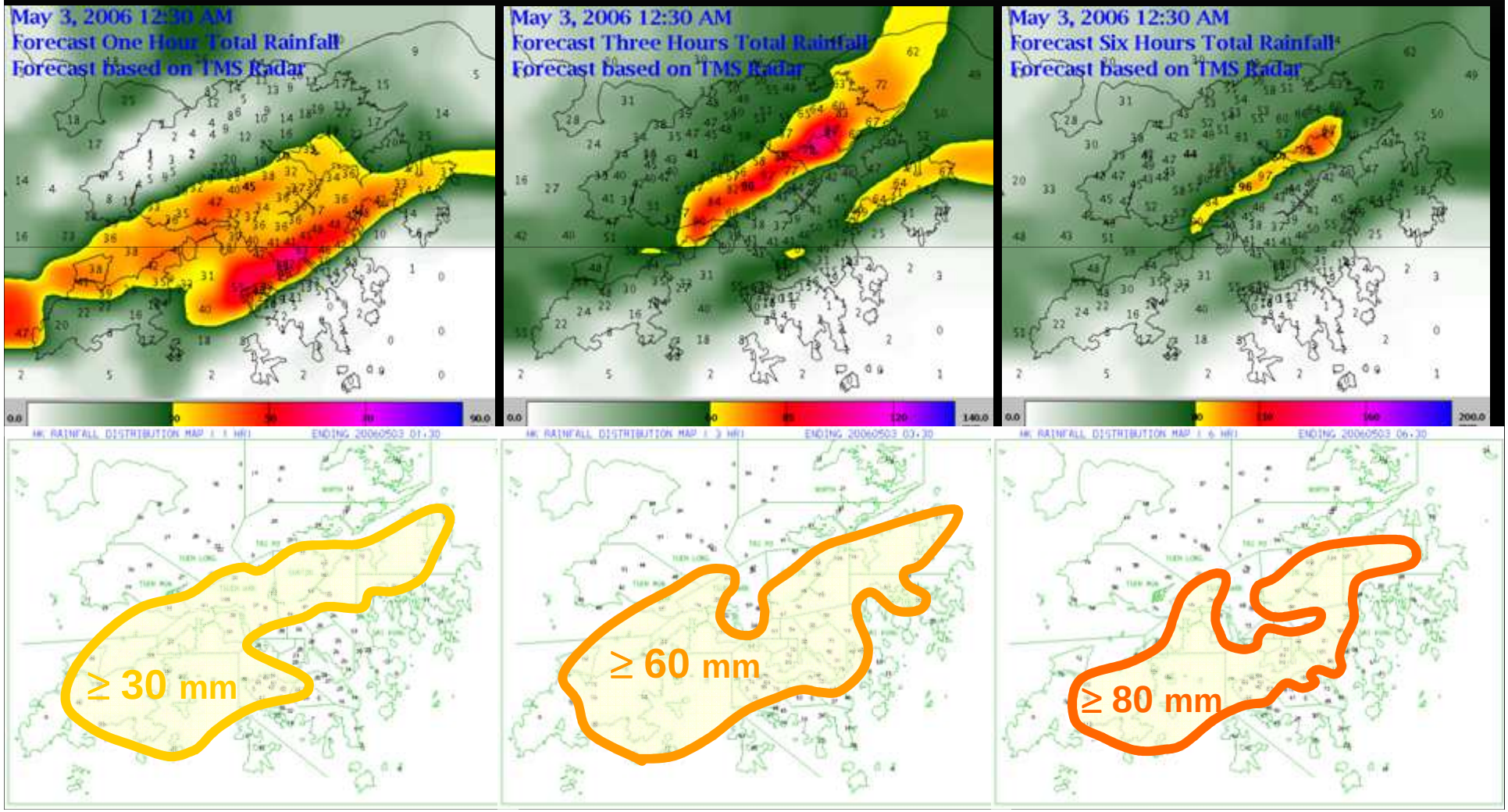


1-6 HOURS QPF
STORM GROWTH & DISSIPATION PROBLEM

SWIRLS Nowcast (top)

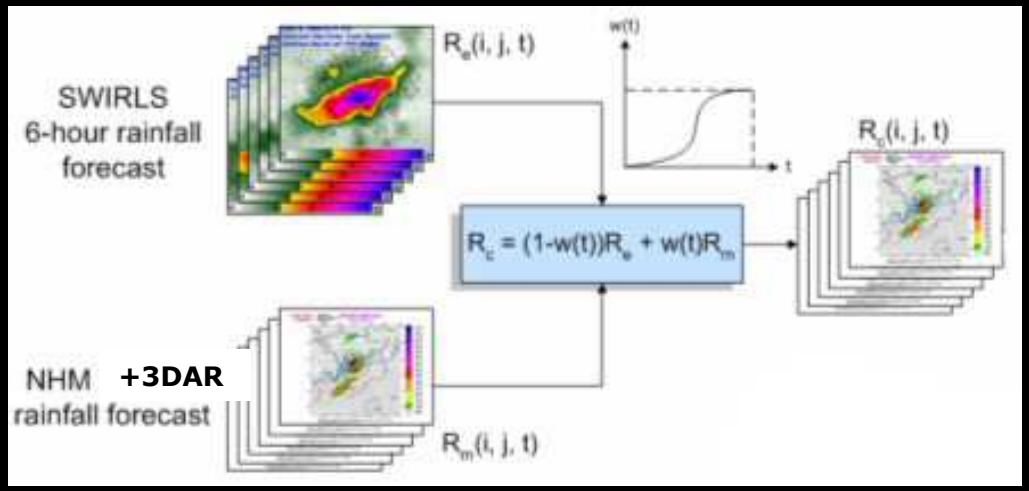
actual (bottom)

1-hour | **3-hour** | **6-hour**



BLENDING LE WITH NWP

- Nowcasting component – LE
  - *0 - 6 hr QPF by extending the linear extrapolation of radar echoes*
- NWP component – Non-hydrostatic Model (NHM)
  - *0 – 6 hr QPF by 2-km non-hydrostatic numerical model*
  - *3DVAR, Doppler, dual-radar 3D wind, GPS/PWV, etc.*



- Spatial & intensity adjusted
- No temporal adjustment
- Dynamic-weighting

DUAL-DOPPLER 3D RADAR WINDS

3-dimensional wind components (u,v,w) are retrieved from the observed radial velocity from 2 radars via minimization of the cost function

$$J = J_o + J_b + J_d + J_s$$

where

J_o = square of difference between the observed radial velocity and the radial velocity of the retrieved 3D radar wind field;

J_b = square of difference between the retrieved 3D radar wind field and the background;

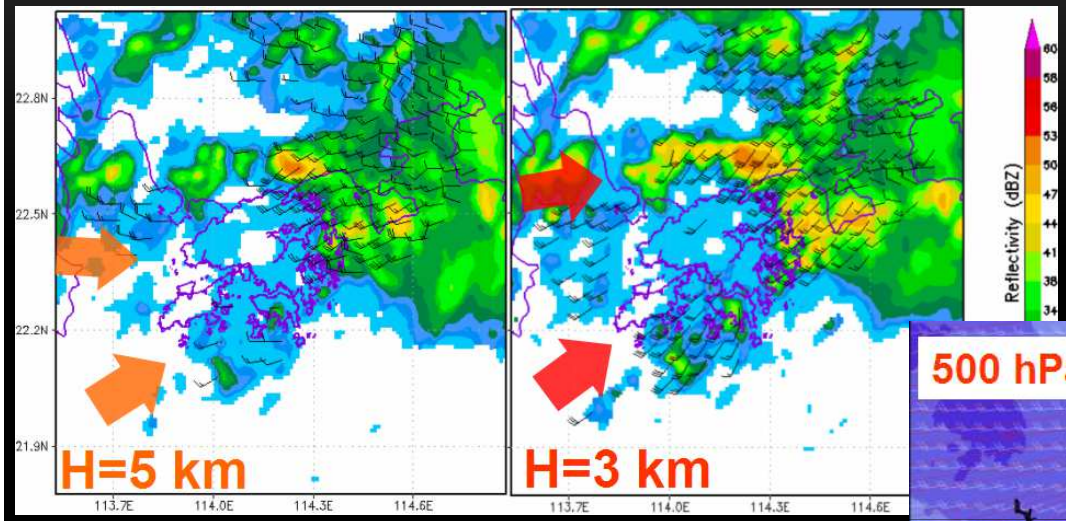
J_d = anelastic mass constraint term;

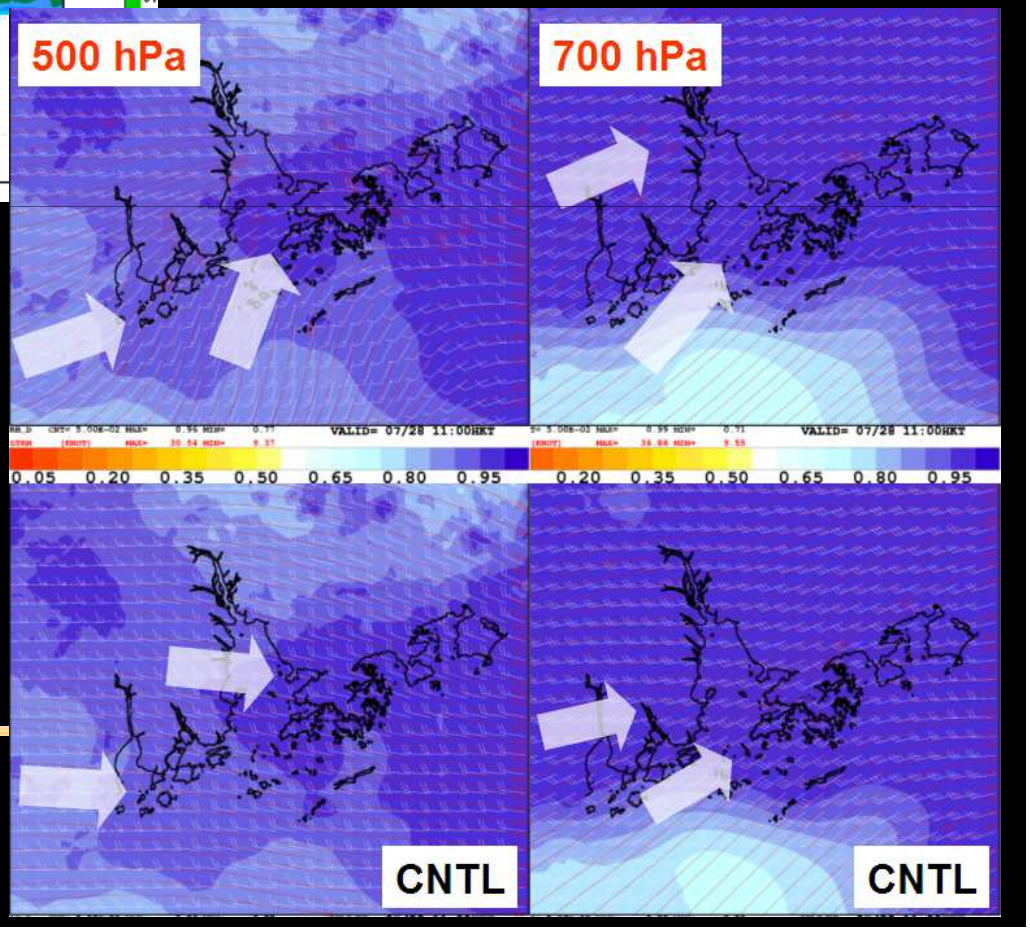
J_s = smoothness constraint (Laplacian of wind components).

1 km x 1 km horizontal resolution
2 – 6 km height in 0.5 km interval
updated every 6 minute
As pseudo-observations on the mesoscale flow features

Shimizu, S., H. Uyeda, Q. Moteki, T. Maesaka, Y. Takaya, K. Akaeda, T. Kato, and M. Yoshizaka, 2008: Structure and formation mechanism on the 24 May 2000 supercell-like storm developing in a moist environment over the Kanto Plain, Japan. Mon. Wea. Rev., 136, 2389–2407

Radar retrieval winds at various levels



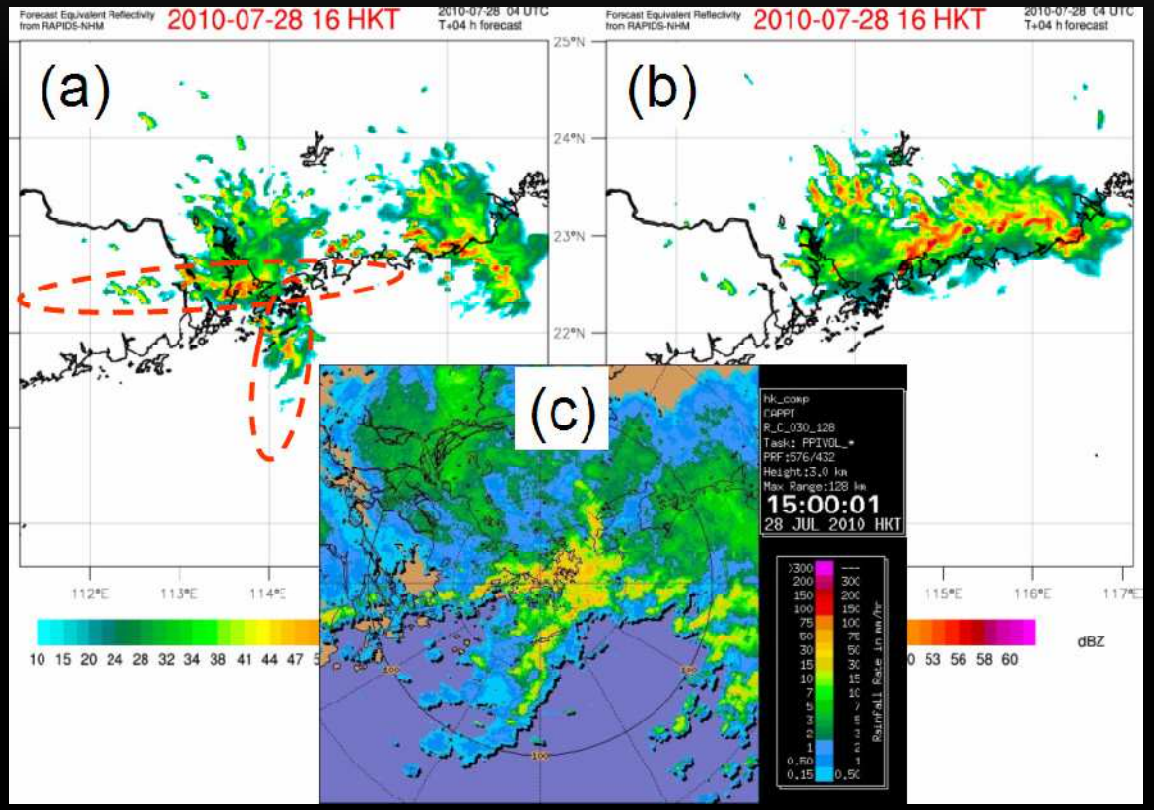


Model 0300UTC Analysis

Better simulate the “Cross-system” pattern with radar 3D wind assimilated

T+4hr F/C

Dual radar 3D wind assimilated



T+4hr F/C

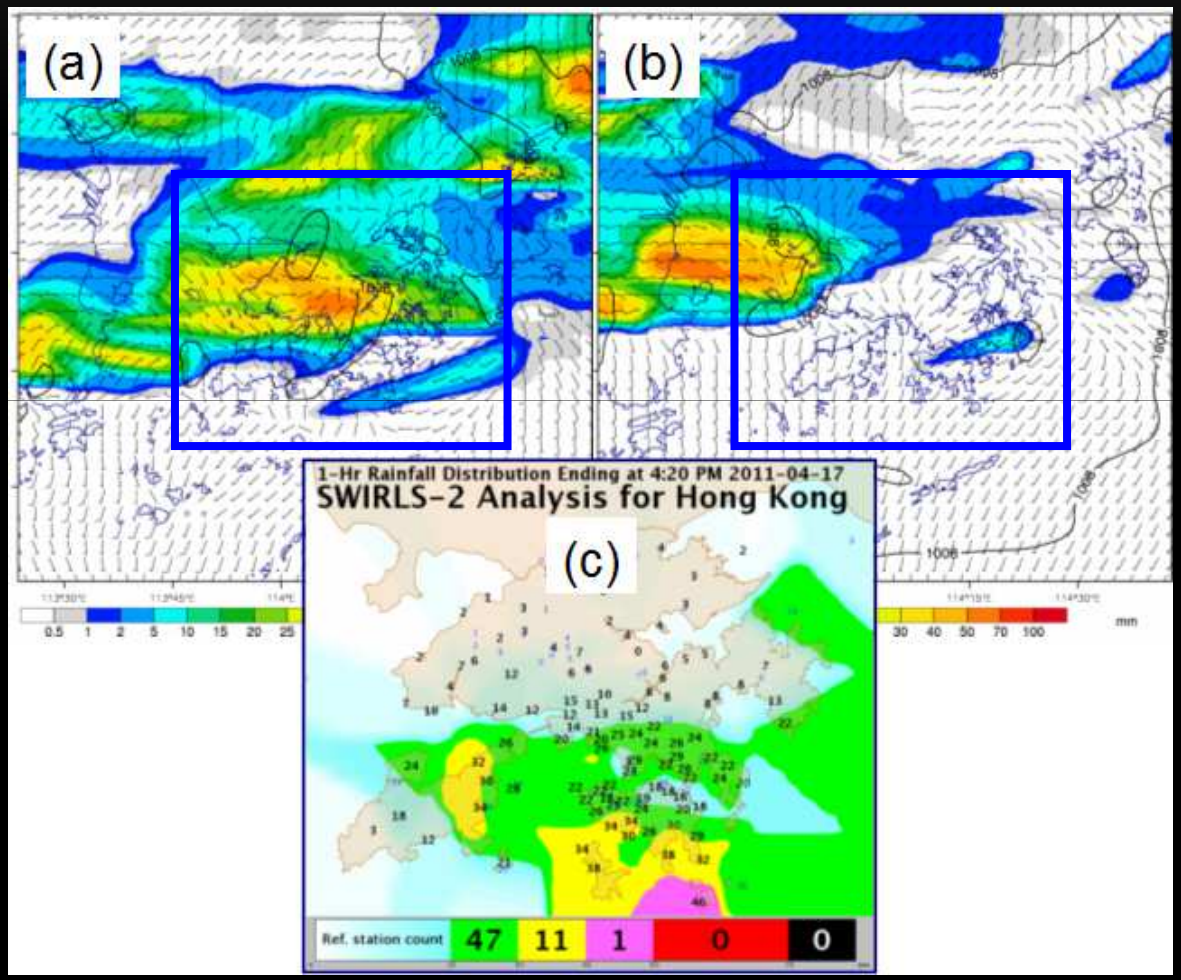
Control
No Dual radar
3D wind

Actual 1hr rainfall

ASSIMILATION OF GPS/PWV

T+5hr F/C

GPS/PWV assimilated



T+5hr F/C

Control
No GPS/PWV

rainfall

Better QPF with GPS/PWV assimilated

PROBLEMS

- Assimilation of high resolution remote sensing data (radar Doppler wind, 3D wind, GPS/PWV, etc.) improved the forecast
- Blending LE and NWP (with phase-correction) improves the skill score, especially in the first 2 hours, but still far from satisfactory
- The model's storm growth/dissipation, timing, intensity need to be improved
- The model's uncertainty needs to be taken care of.

Probabilistic approach?

EXPERIENCE IN PROBABILISTIC NOWCASTING

NOWCASTING OF CLOUD-TO-GROUND LIGHTNING FOR THE HONG KONG INTERNATIONAL AIRPORT

RED/AMBER Lightning Alert

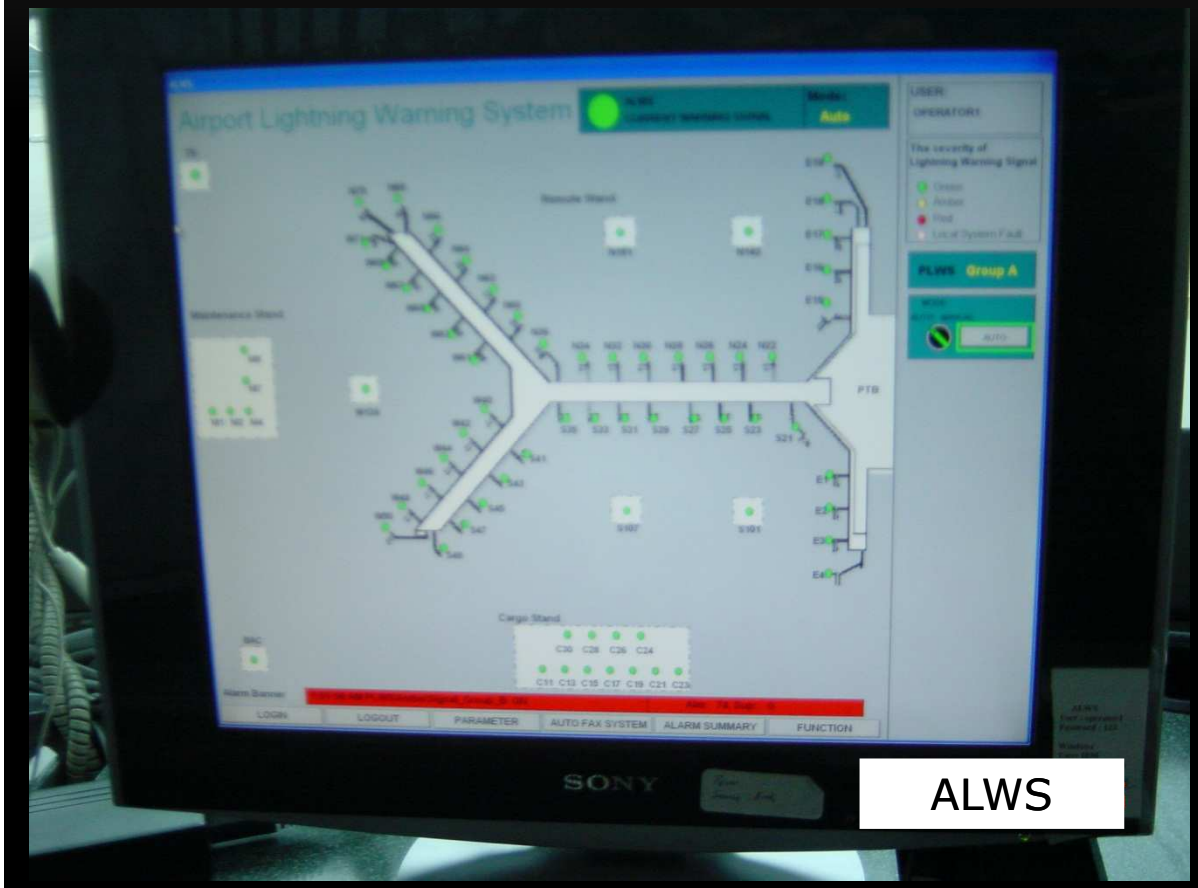
⇩ fully-automatic

Disseminated to users

- All ground operations have to stop and take measures to protect lives against lightning strikes
- Re-fueling, embarkment /disembarkment, baggage/cargo handling would be delayed bringing major disruption to airport operation**s**

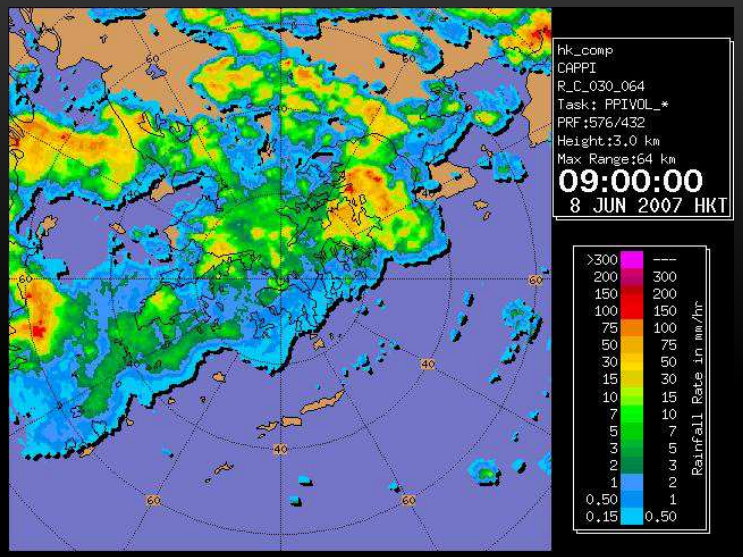
-> **high precise lightning alerting system**

AIRPORT LIGHTNING WARNING LIGHT AND SIREN

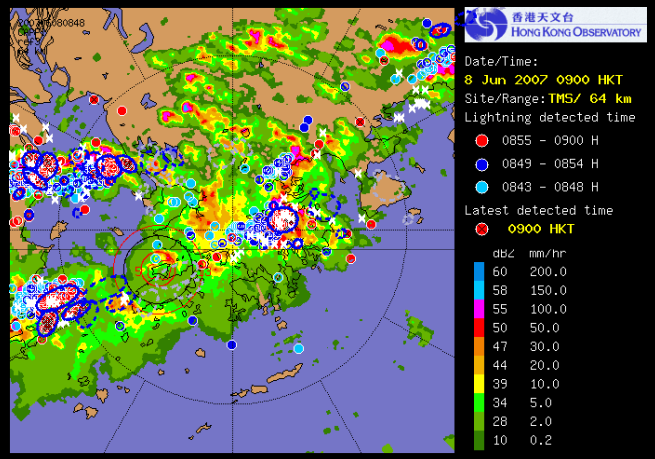


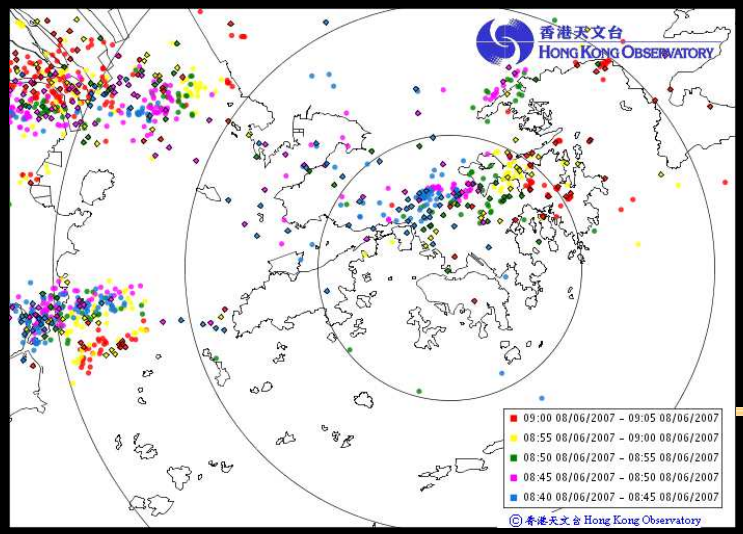
ALWS

ATLAS



Weather Radar -
Thunderstorm intensity and movement

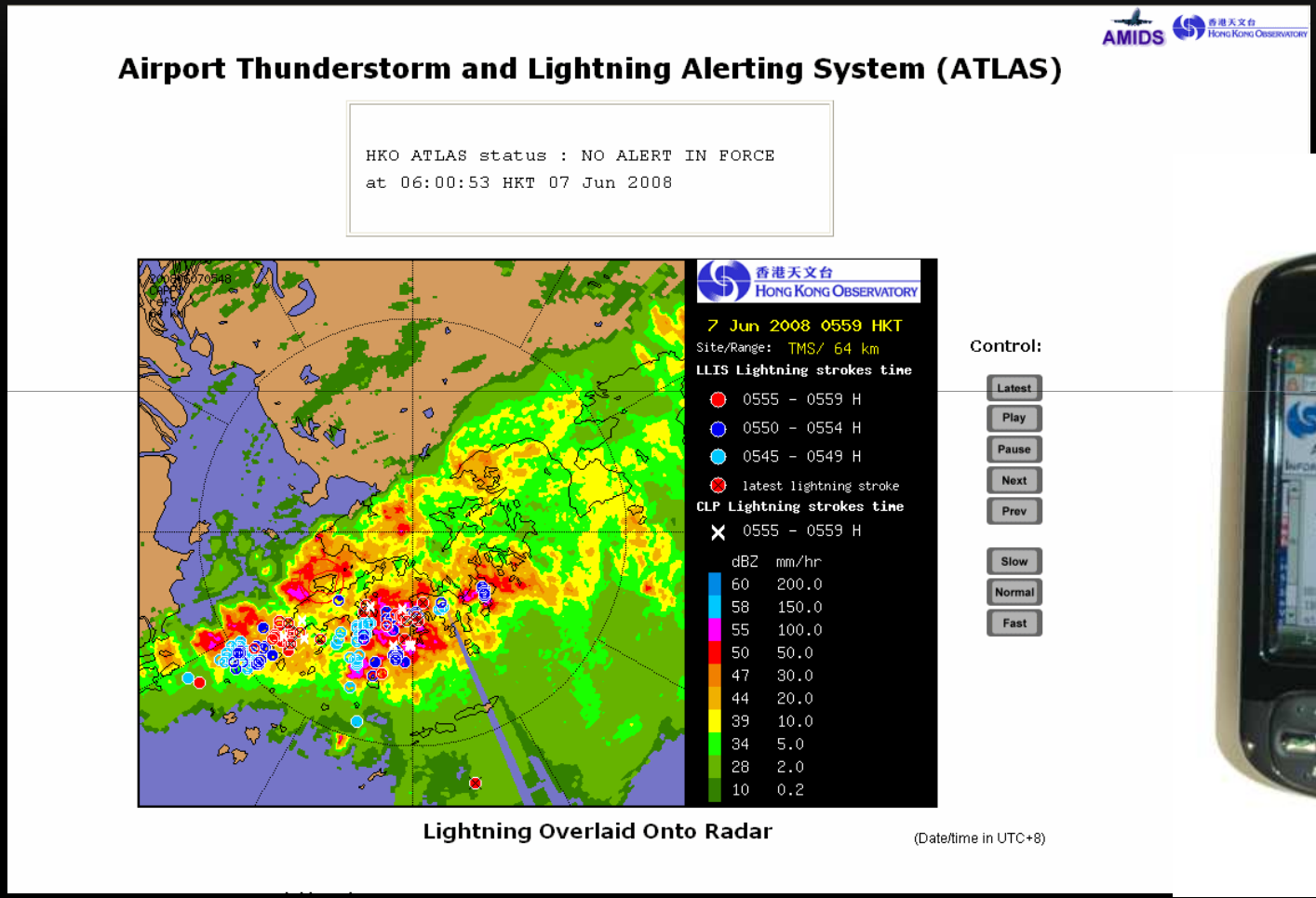




updated every minute

LLIS network –
Cloud-to-Ground (CG) lightning location

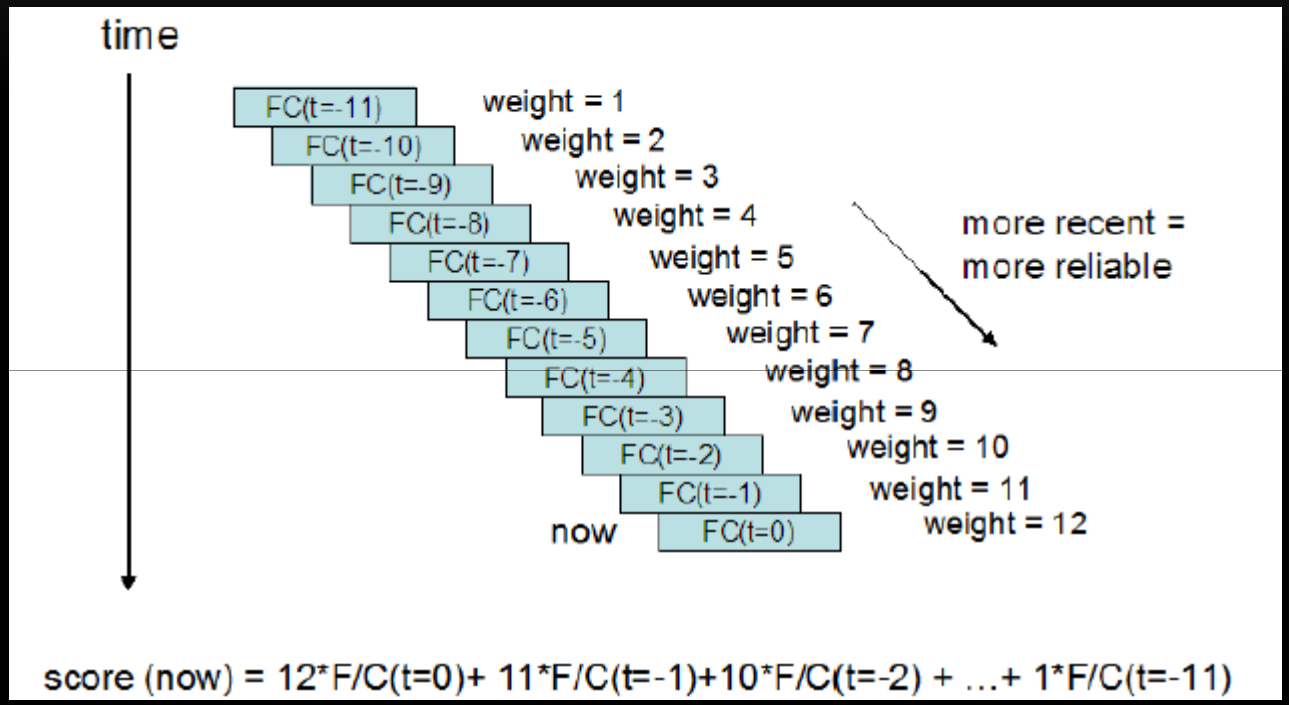
ATLAS ALERT VIA INTERNET AND MOBILE



Informative graphical product

Simple texture message

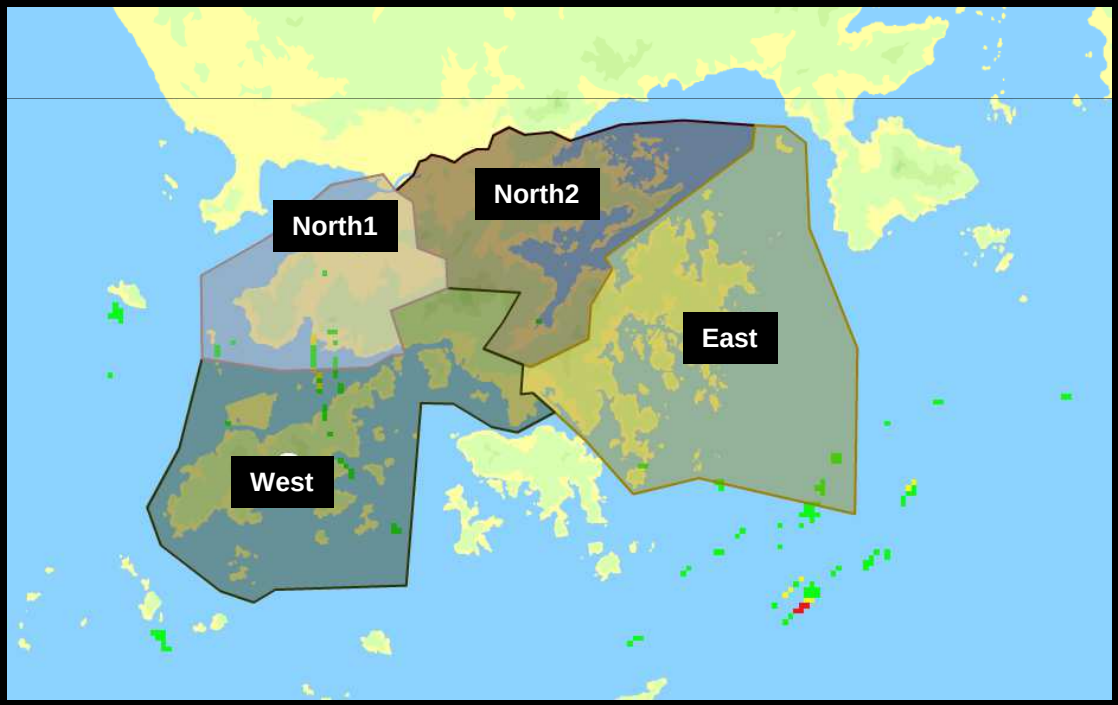
TIME-LAGGED ENSEMBLE NOWCAST APPROACH



POD > 90%, FAR < 10% (since 2008)
No casualty since the introduction of ATLAS

PROBABILITY LIGHTNING NOWCAST FOR POWER COMPANY

- Objective: To forecast and alert the possibility of 3 or more power disruption events over 4 zones (overland) due to lightning in the next 2 hours
- HKO is requested to forecast the “number of CGs” in the next 2 hours, with uncertainty information provided

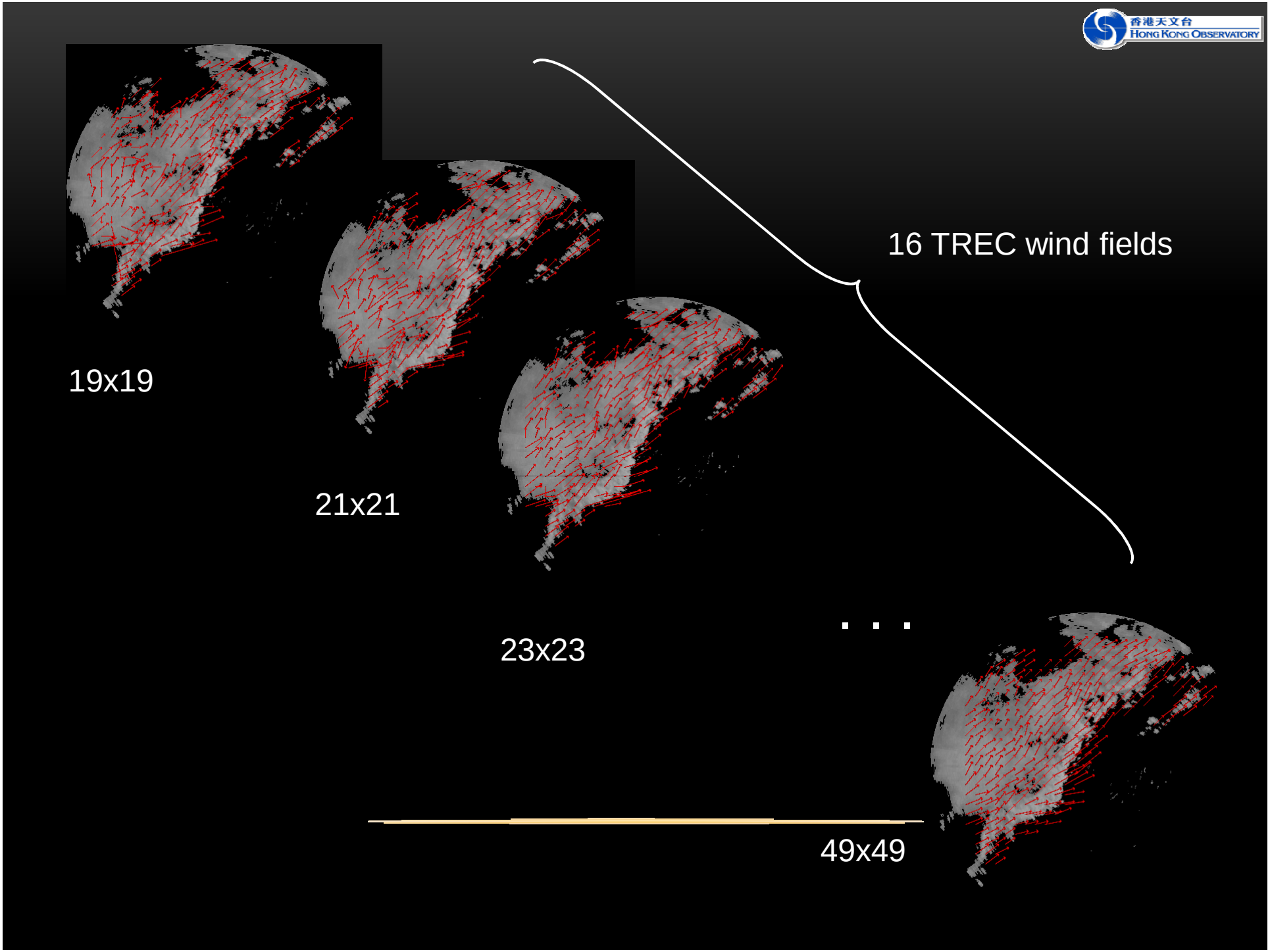


ENSEMBLE NOWCASTING APPROACH

(CONCEPT BORROWED FROM ECMWF EPS)

- The uncertainty could emerge from
  - motion field – mixture of small scale and large scale
  - fluctuation of motion vector with time
  - storm growth and dissipation

- ensemble TREC (eTREC)
  - Varying the size of the “box” in the TREC correlation algorithm to find out different TREC wind fields
  - 16 box sizes -> 16 TREC wind fields
- smaller box -> microscale movement
  larger box -> macroscale movement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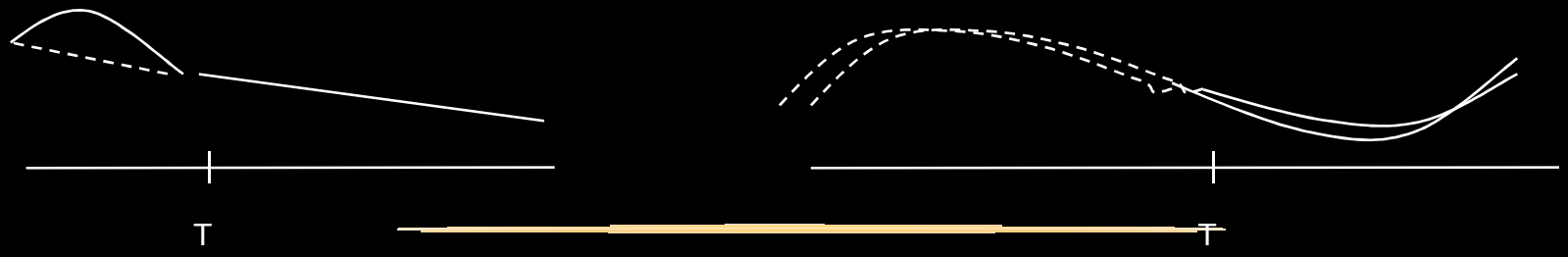
16 TREC wind fields
19x19
21x21
23x23
. . .
49x49

- For the growth and dissipation, include trending:
  - Linear trend
    - Multiple linearly each of the 16 eTREC members by a factor derived by the change of the no. of CG strokes in the past hour
  - Nonlinear trend
    - Multiple each of the 16 eTREC members by following the change profile of the no. of CG strokes in the past 3 hours

- For the fluctuation of storm movement, include time-lagged ensemble by involving T and T-6min ensemble nowcasts to generate a grand ensemble
  - grand (linear) ensemble nowcast = 16 (no trend) + 16 (T-0min linear trend) + 16 (T-6min linear trend) members = 48 members
  - OR grand (nonlinear) ensemble nowcast = 16 (no trend) + 16 (T-0min nonlinear trend) + 16 (T-6min nonlinear trend) members = 48 members



linear trend

nonlinear trend

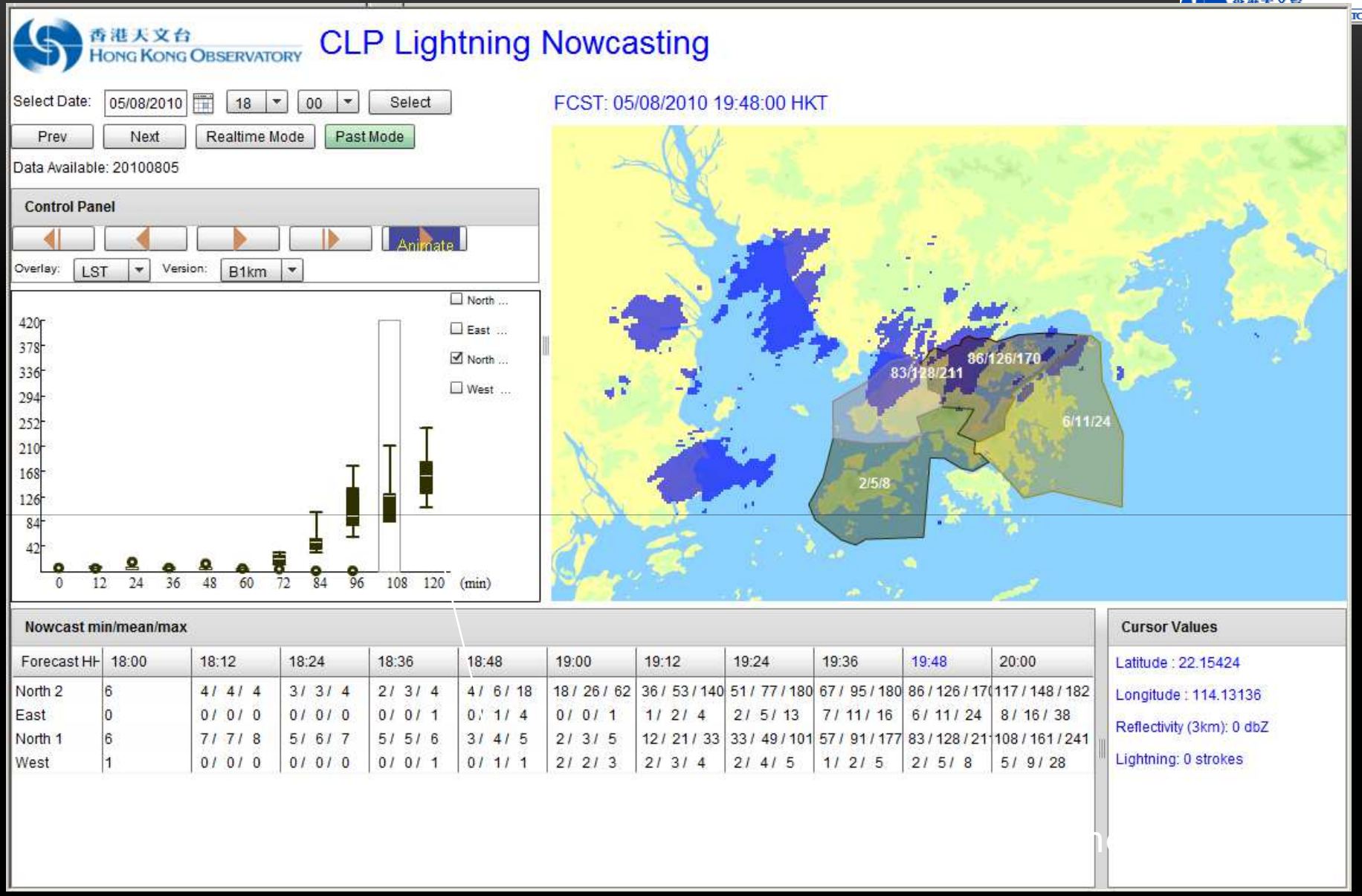
TECHNICAL FEASIBLE

1x superblade server, dual quadcore ->
16 threads running in parallel

48x ensemble members

16x notrend nowcasts	-> 60sec
16x T-6 linear/nonlinear trend nowcasts	-> 40sec
16x T-0 linear/nonlinear trend nowcasts	-> 40sec
statistics computation	-> 20sec
	< 3 min

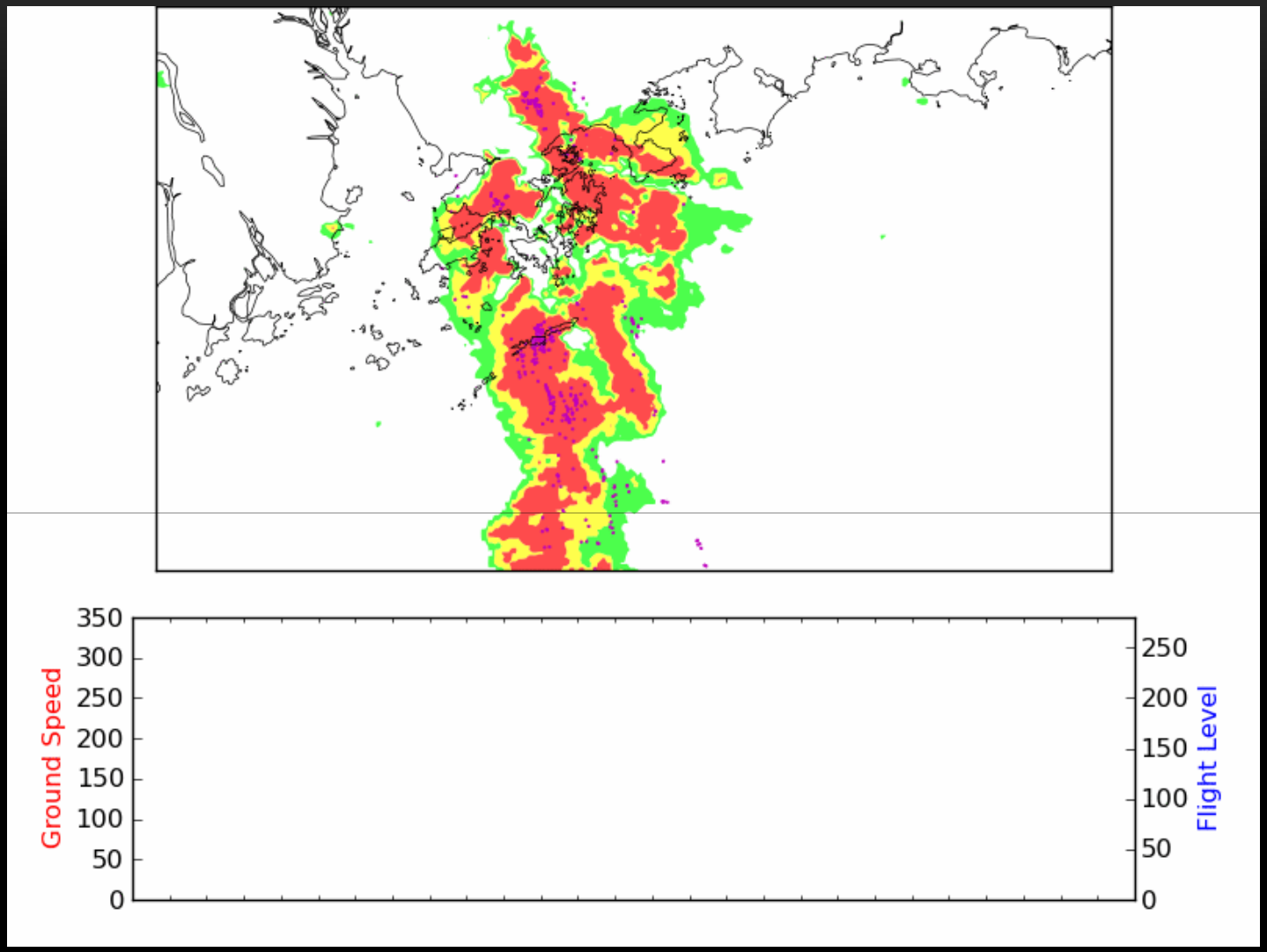
=> ENS update frequency (6 min) feasible



Forecast HH	18:00	18:12	18:24	18:36	18:48	19:00	19:12	19:24	19:36	19:48	20:00
North 2	6	4 / 4 / 4	3 / 3 / 4	2 / 3 / 4	4 / 6 / 18	18 / 26 / 62	36 / 53 / 140	51 / 77 / 180	67 / 95 / 180	86 / 126 / 17	117 / 148 / 182
East	0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 1	0 / 1 / 4	0 / 0 / 1	1 / 2 / 4	2 / 5 / 13	7 / 11 / 16	6 / 11 / 24	8 / 16 / 38
North 1	6	7 / 7 / 8	5 / 6 / 7	5 / 5 / 6	3 / 4 / 5	2 / 3 / 5	12 / 21 / 33	33 / 49 / 101	57 / 91 / 177	83 / 128 / 21	108 / 161 / 241
West	1	0 / 0 / 0	0 / 0 / 0	0 / 0 / 1	0 / 1 / 1	2 / 2 / 3	2 / 3 / 4	2 / 4 / 5	1 / 2 / 5	2 / 5 / 8	5 / 9 / 28

Customer's feedback, "By having the alert service, we could mobilize our operation and emergency team early, and expedite power restoration in case any equipment fails due to lightning. At the same time, the lightning information could facilitate the company to dispatch the emergency crew more safely and efficiently."

GREATER CHALLENGES – AVIATION REQUIREMENTS

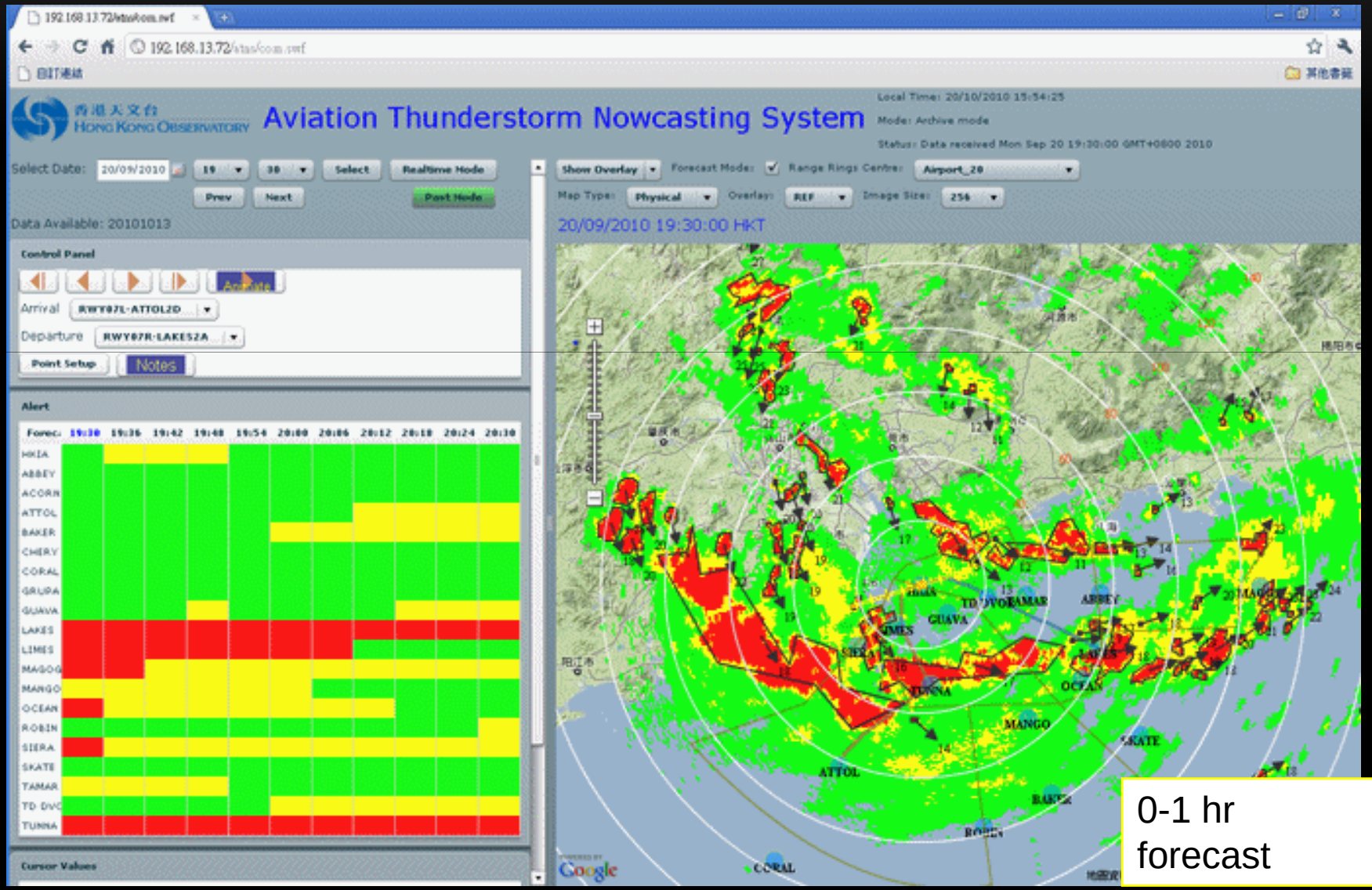

Ground Speed
350
300
250
200
150
100
50
0
Flight Level
250
200
150
100
50
0

AVIATION CONVECTION FORECAST IS A HIGHLY DEMANDING 4-DIMENSIONAL PROBLEM

- position, height and time
- Intensity, onset, longevity, probability, …
- Trajectory-Based
- Especially important for busy/growing airports worldwide
- Not single effort of MET service – close collaboration with ATM

"The Envisioned Aviation System and Nowcasting Requirements" (Thursday)

Aviation Thunderstorm Nowcasting System (ATNS)
Specific Forecast for waypoints 0-1 hour



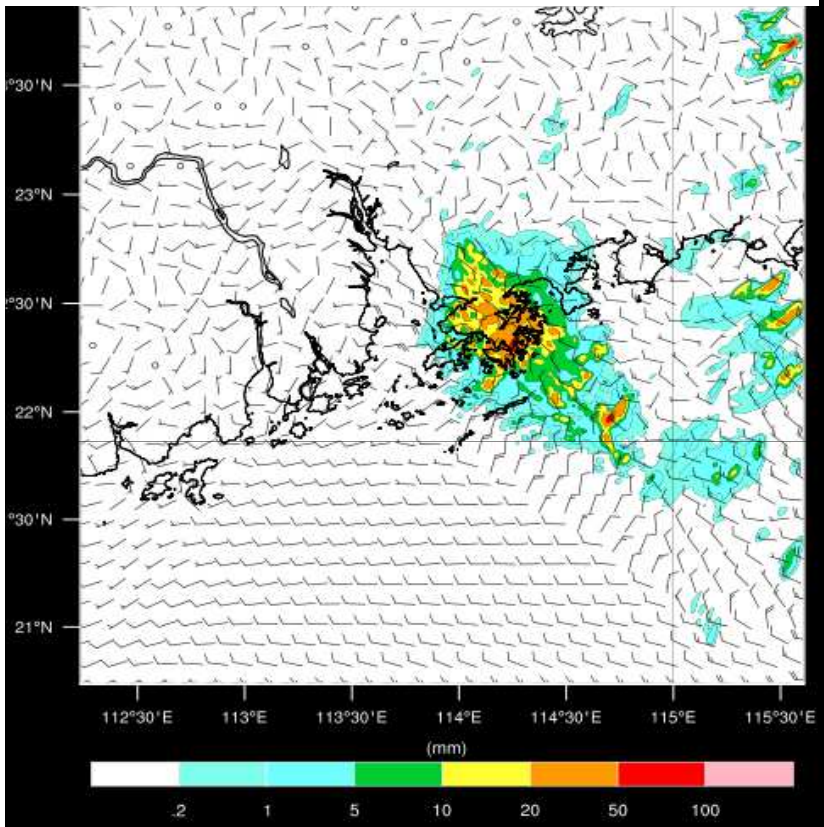
0-1 hr forecast

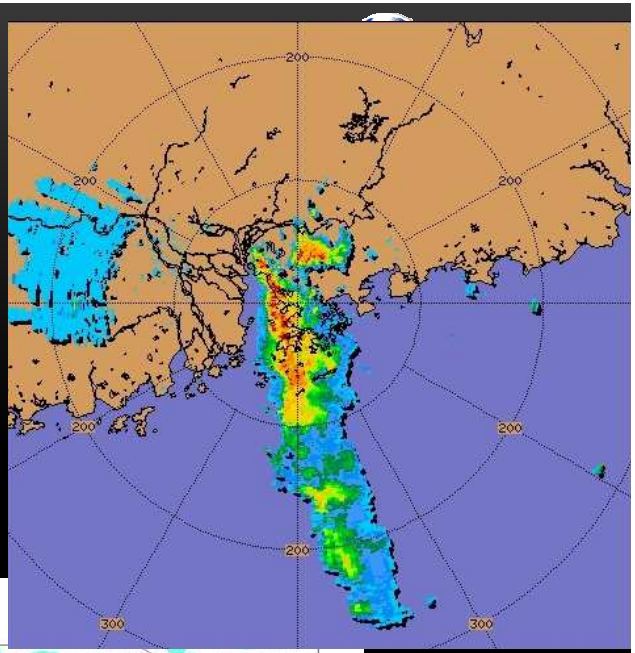
OTHER NOWCASTING NEEDS FROM AVIATION COMMUNITY

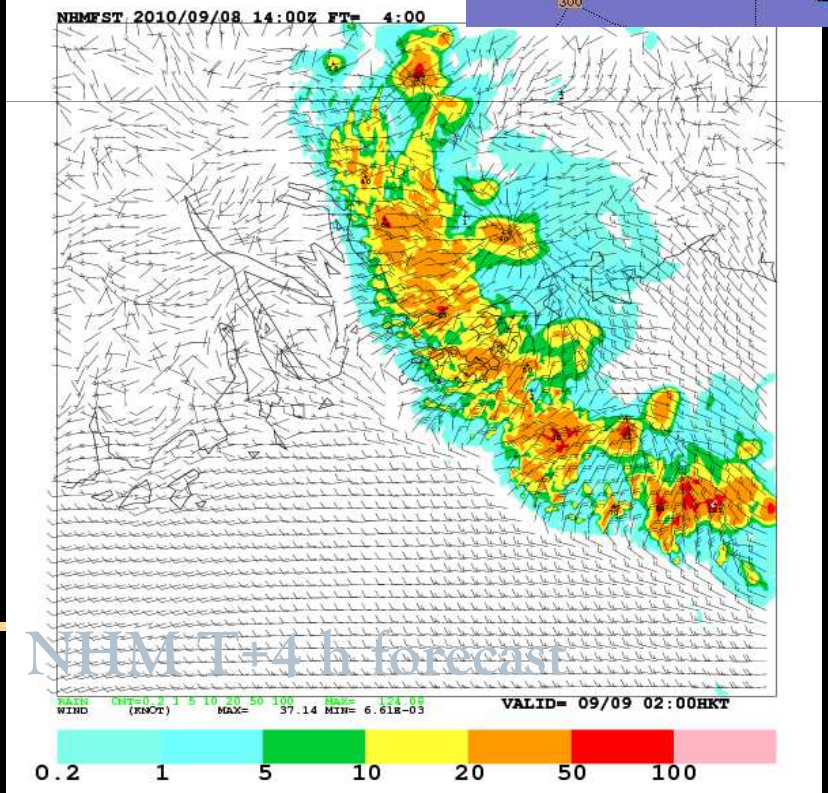
- Besides convection …
  - Low level windshear
  - Crosswind
  - Low level turbulence
  - Visibility (haze/dust, mist/fog)
  - …

ULTRA-HIGH RESOLUTION AVIATION MODEL

WRF T+4 h forecast





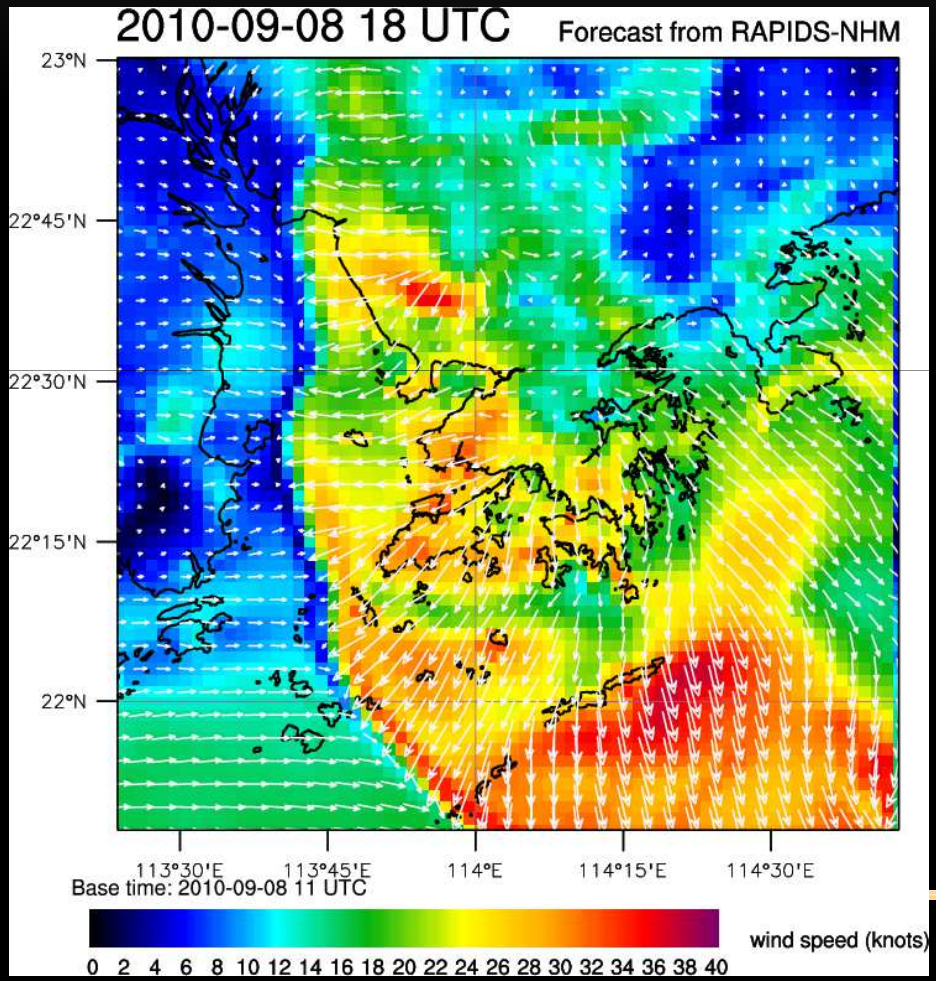


NHM T+4 h forecast

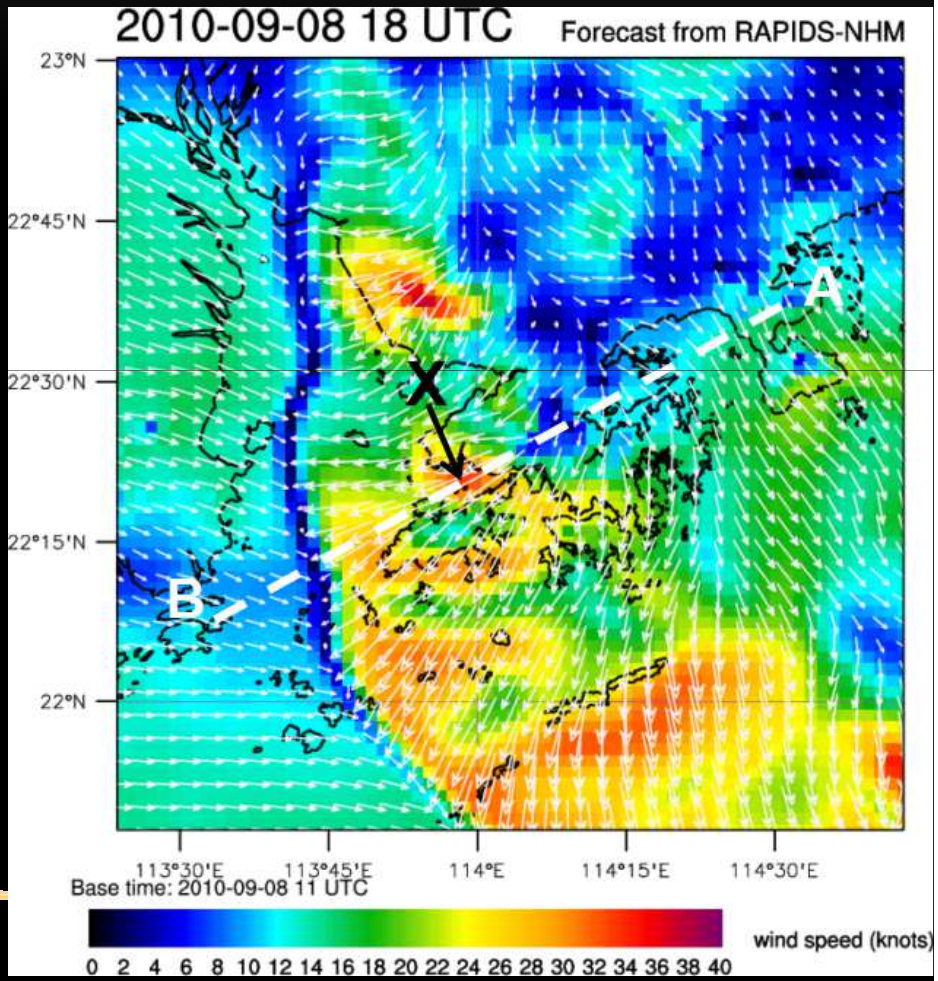
Δx=600m

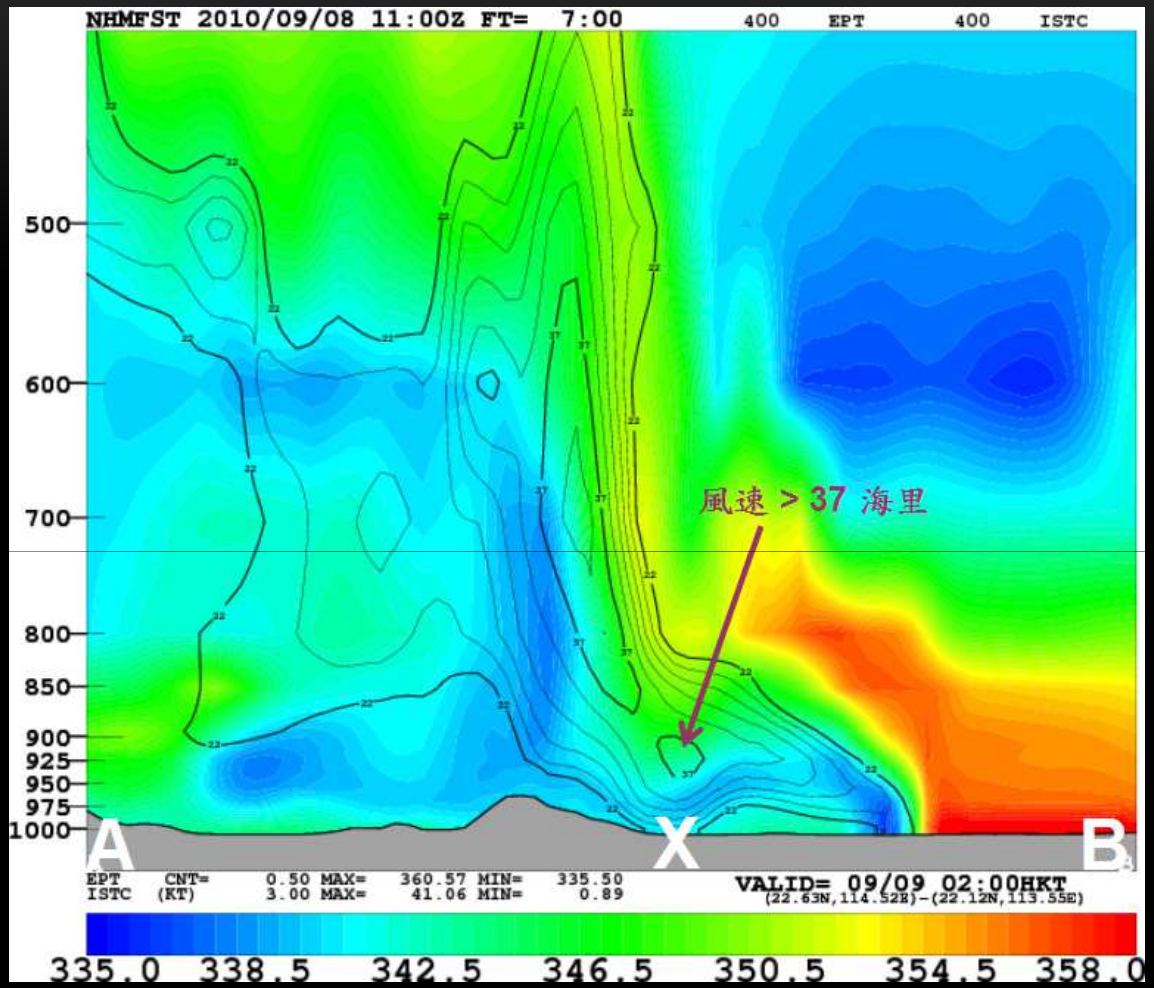
N.B. model forecast at a time lag of about 1.5 hr on the passage of squall line

RAPIDS-NHM forecast for surface wind speed and wind direction (arrows) and gust (color shading in knots)



RAPIDS-NHM forecast for wind speed (color) and wind direction (arrows) at 975 haps level



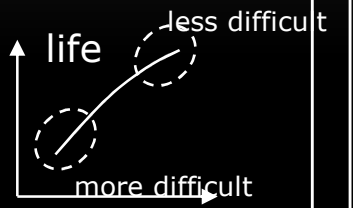


Vertical cross section along AB showing wind stomach (contour, unit in knots) and EPT (color, unit in K). Stomach contours are drawn with an interval of 3 knots for areas exceeding 22 knots.

IDENTIFIED IMPROVEMENT AREAS

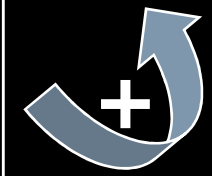
Modeling

- Higher density (spatial-temporal) observations
- Hi-Fi DA
- Spin-up/hot start
- Microphysics
  - Dual-pol radar products
- Initiation/growth/dissipation
  - Storm sustainability –storm dependent
  - Multiscale interaction
    single cell, multicellular, mesoscale, organized systems (squall line, tropical cyclone)
- Probabilistic forecast
  - How to generate useful probabilities?
- How to verify Impact?



Nowcast

- How to better utilize NWP parameters?
  - Deterministic and
  - probabilistic
- How to blend with NWP?



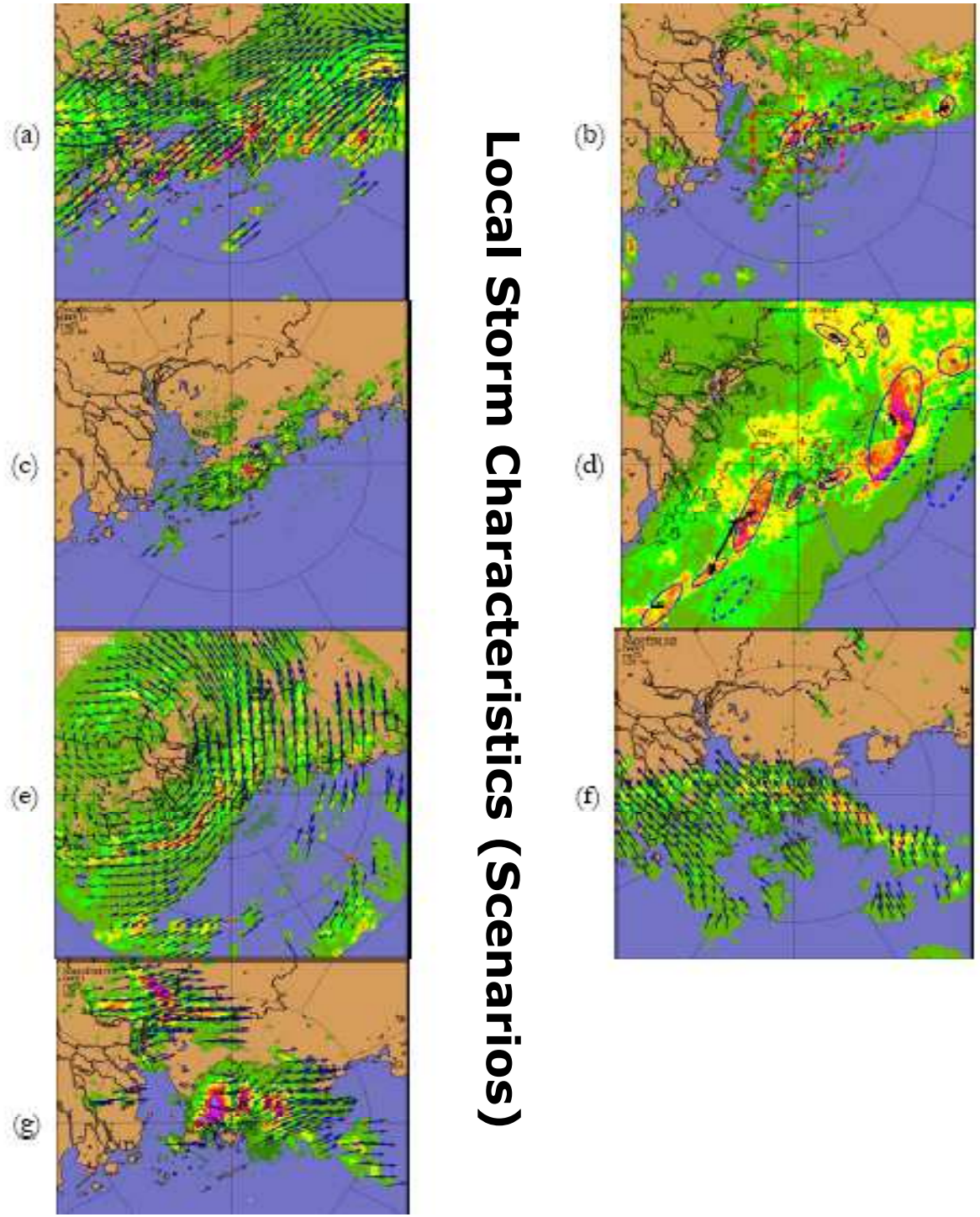
Improved Nowcast

- How to fully utilize NWP data conceptual model (O-O) vs gridded, digital forecast
- Extreme /High Impact events matter – “call-to-action”

IN SHORT

- We did see improvements, but …
- Some weather phenomena are difficult to be nowcast than others, the limitation of LE (the limit of linear extrapolation)
- High resolution modeling is still far from satisfactory in terms of high impact weather
- Smart blending is required but how?
- Requires human knowledge to fill the insufficiency

Local Storm Characteristics (Scenarios)



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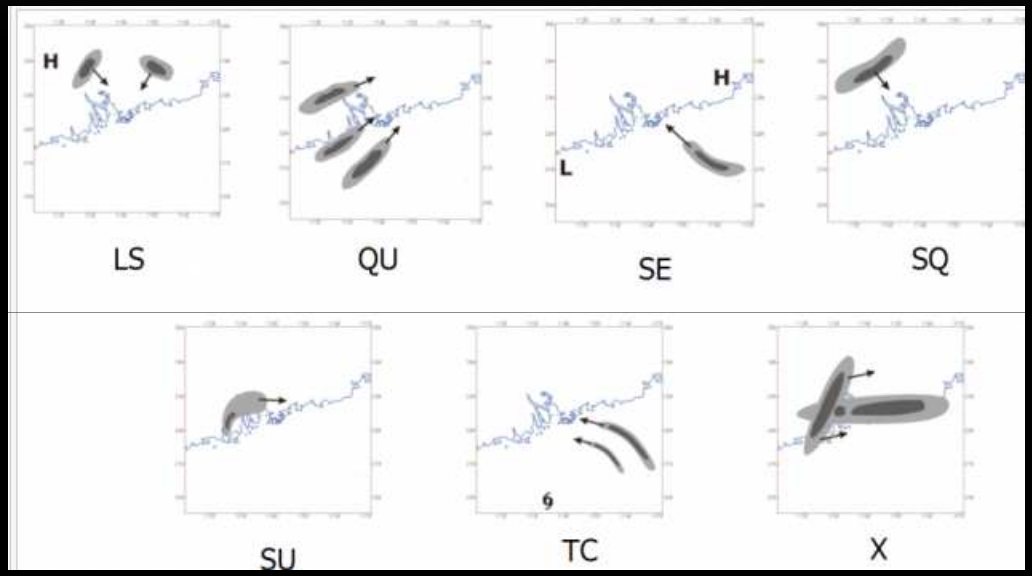
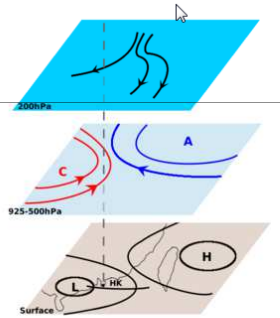
RAINSTORM CHARACTERISTICS
- FROM RADAR PERSPECTIVE
- FROM SYNOPTIC FORCING PERSPECTIVE



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.



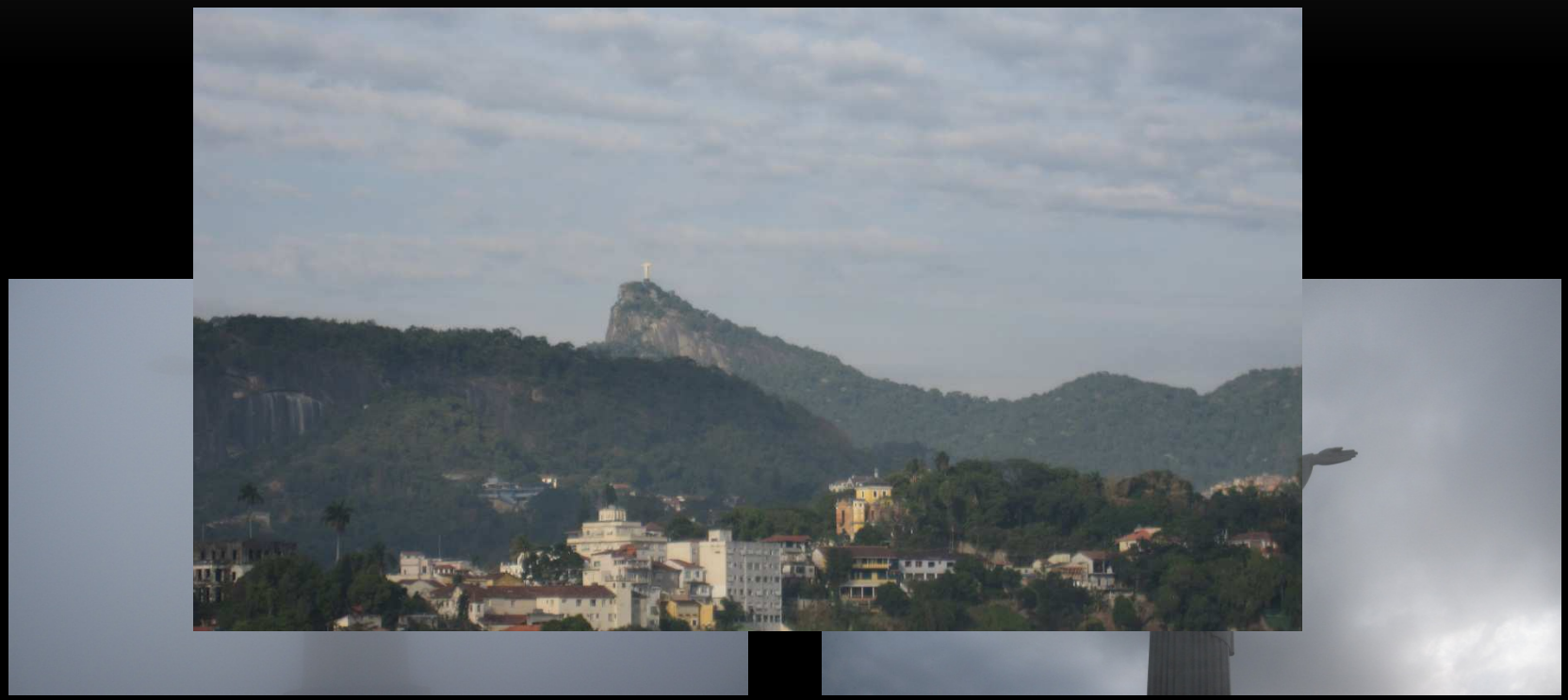
Type Summary

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

Radar perspective
Rainstorm Phasebook

SE, CP, TC, LS, SW, MTN, MTS

TO FIND THE TRUE …
TO VISIT CHRISTO REDENTOR



but when I get closer !?!?

"I want to see more with patience and perseverance !

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THANK YOU
Q & A