NOWCASTING SYSTEMS AND SERVICES IN HONG KONG

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Nowcasts are precise in weather element, time and space!

Extreme events!

“Call to Action!”

Stakeholders:
- General public
- Government departments
- Transportation
- Public utilities
- ...

0-6 hours ahead is a kind of norm
LOCAL PUBLIC WEATHER FORECAST AND WARNING SERVICES ON HIGH IMPACT WEATHER

- **Tropical Cyclone**
  - TC within 800 km of HK
  - Winds blowing 41-62 km/hr within 12 hours over Harbour

- **Rainstorm & related**
  - ≥ 30 mm/hr
  - ≥ 50 mm/hr

- **Landslip**
  - ≥ 70 mm/hr

- **Special Announcement of Flooding**
  - ≥ 50 mm/hr

- **Thunderstorm**
  - Winds blowing 63-117 km/hr at half ref. stn
  - Increasing gale or storm force winds

- **Strong Monsoon**
  - Winds blowing 118 km/hr or above

- **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
    - Various scales treated
    - Capture better large scale (system) movement in comparison with TREC
TREC (Tracking Radar Echoes by Correlation)

50km/hr SW'lies with some embedding short waves

3 km TREC wind of an intense rainstorm

Stronger to the right, weaker to the left

3 km TREC wind of a tropical cyclone
# SWIRLS2 PRODUCTS

<table>
<thead>
<tr>
<th>Product Type</th>
<th>Forecast Element</th>
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<tbody>
<tr>
<td>Severe weather</td>
<td>lightning, downburst/gust hail</td>
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![Map showing forecast elements](image)
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

Linus HY Yeung “Recent Developments and Applications of the SWIRLS Nowcasting System in Hong Kong”
1-6 HOURS QPF
STORM GROWTH & DISSIPATION PROBLEM

May 3, 2006 12:30 AM
Forecast One Hour Total Rainfall
Forecast based on TMS Radar

May 3, 2006 12:30 AM
Forecast Three Hours Total Rainfall
Forecast based on TMS Radar

May 3, 2006 12:30 AM
Forecast Six Hours Total Rainfall
Forecast based on TMS Radar

≥ 30 mm
≥ 60 mm
≥ 80 mm
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

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

1-Hr Rainfall Distribution Ending at 4:20 PM 2011-04-17

SWIRLS-2 Analysis for Hong Kong

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

- 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 operations

-> **high precise** lightning alerting system
AIRPORT LIGHTNING WARNING LIGHT AND SIREN
ATLAS

Weather Radar - Thunderstorm intensity and movement

updated every minute

LLIS network – Cloud-to-Ground (CG) lightning location
ATLAS ALERT VIA INTERNET AND MOBILE

Airport Thunderstorm and Lightning Alerting System (ATLAS)

HKO ATLAS status: NO ALERT IN FORCE at 06:00:53 HKT 07 Jun 2008

Lightning Overlaid Onto Radar

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
• 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
TECHNICAL FEASIBLE

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

\[
\begin{align*}
16x \text{ notrend nowcasts} & \rightarrow 60\text{sec} \\
16x \text{ T-6 linear/nonlinear trend nowcasts} & \rightarrow 40\text{sec} \\
16x \text{ T-0 linear/nonlinear trend nowcasts} & \rightarrow 40\text{sec} \\
\text{statistics computation} & \rightarrow 20\text{sec} \\
\end{align*}
\]

\[
\begin{align*}
&< 3 \text{ min} \\
\Rightarrow & \text{ ENS update frequency (6 min) feasible}
\end{align*}
\]
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
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
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

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

Δx=600m
RAPIDS-NHM forecast for surface wind speed and wind direction (arrows) and **gust** (color shading in knots)
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)
RAINSTORM CHARACTERISTICS
- FROM RADAR PERSPECTIVE
- FROM SYNOPTIC FORCING PERSPECTIVE

Forcing Type: MTS

Monsoon Trough South (MTS)

MTS occurs over the south China coast or southern part of the South China Sea (SCS) when the SW monsoonal flow converges with SE flow at the SW flank of the Pacific ridge. Depending on the relative dominance of the Pacific ridge and SW monsoonal flow, MTS usually appears as a broad trough over the SCS. Intense and persistent convection 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.

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Radar perspective
Rainstorm Phasebook

SE, CP, TC, LS, SW, MTN, MTS
TO FIND THE TRUE ...
TO VISIT CHRISTO REDECTOR

but when I get closer... "I want to see more with patience and perseverance!"
THANK YOU
Q & A