The Hong Kong Observatory’s Operational Data Management Systems

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HKO
ECMWF Meteorological Operational Systems Workshop – November 2009
Content

• Briefly introduce data management systems storing observational data in HKO
• Introduce key components of the Decision Support System (DSS) in HKO using observational data extensively
• Review database structure of two typical applications in HKO and introduce the use of Oracle Real Application Cluster (RAC) and Data Guard technologies on these databases
Data Management Systems in HKO

- **GTS data** (SYNOP, radiosonde, SHIP, …)
  - Used since 2003
  - Oracle 9i on IBM HACMP cluster
  - Data exchange with RTH Tokyo, RTH Beijing, NMC Macau, met. centres of nearby cities like Guangzhou, Shenzhen, etc.
  - Upgrade planned for early 2010, 11g?

- **AWS data**
  - Used since 2007
  - Oracle 10g
  - Local (1 min frequency, ~100 stations)
  - Regional (10 min to hourly frequency, ~450 stations)

- **Rain gauge data**
  - Use since 2007
  - Oracle 10g
  - ~140 stations of HKO, GEO (Geotechnical Engineering Office), DSD (Drainage Service Department)

- **Reporting, forecast, warning bulletins data**
  - Use since 2007
  - Oracle 10g on RAC with Data Guard
  - Support Public Weather Service
Decision Support System in HKO

- SWIRLS – Short-range Warning of Intense Rainstorm in Localized System
- LAPS – Local Analysis and Prediction System
- NHM – Non-Hydrostatic Model
- RAPIDS – Rainstorm Analysis and Prediction Integrated Data-processing System
- TIPS – Tropical Cyclone Information Processing System
- MINDS – Meteorological Information Dissemination System
HKO’s Nowcasting system - SWIRLS

• SWIRLS
  – Short-range (1-6 hours)
  – Warning of
  – Intense (≥30 mm per hour)
  – Rainstorm in
  – Localized (10 – 100 km)
  – Systems

• in operation since April 1999
• originally designed for rainstorms
• evolving to handle other severe weathers
• 2nd generation in operational trial in 2009
Observation Network
Raingauge Networks

Total no. ~ 140, updated every 5 mins, mean separation ~ 1.5 km
Doppler Weather Radar

TDWR (since 1996)

S-band
10cm

Tai Mo Shan (since 1999)

C-band,
5cm
TDWR

TDWR (since 1996)

S-band
10cm

Tates’ Cairn (since 1994)
Lightning Location Detection Network

- Sites provided by HKO, SMG and GMB
- Equipment provided by HKO
- Lightning data shared by HKO, SMG and GMB
香港天文台『小渦旋』臨近預報系統 — SWIRLS
The Fully Automated Nowcasting System of the Hong Kong Observatory for Short-range Warning of Intense Rainstorms in Localized Systems

- 多普勒天氣雷達 Doppler Weather Radar
- 氣象衛星 Meteorological Satellite
- 全球衛星定位系統 Global Positioning System
- 自動無線電 Automatic Weather Station
- 自動雨量計 Automatic Raingauge
- 探空儀 Radiosonde
- 氣流解析儀 Wind Profiler
- 閃電雷達 Lightning Information
- 數值模擬 Numerical Model
- SWIRLS 高性能電腦系統 SWIRLS Supercomputer Systems
- 雷達自動追蹤和外推 Radar Echo Tracking & Extrapolation
- 雷達自動雨量分析 Radar-Rainage Rainfall Analysis
- 定量、概率降雨預報 Quantitative & Probabilistic Precipitation Forecast
- 強風暴追蹤及預報 (閃電、狂風、冰雹) Severe Storm Tracking & Forecast (lightning, squalls & hail)
- 大氣穩定度分析 Atmospheric Stability Analysis
- 中小尺度大氣分析 Local & Mesoscale Analysis
- 數值模式預報融合 Blending with Numerical Model
- 大氣水汽含量分析 Atmospheric Water Vapour Analysis
- 圖象用戶介面與網頁製作 Graphical User Interface & Web Page Production
- 氣候統計案例資料庫 Climatological Case Book
- 暴雨 Rainstorm
- 水浸 Flooding
- 山泥傾倒 Landslip
- 閃電 Lightning
- 狂風 Squalls
- 冰雹 Hail
- 熱帶氣旋 Tropical Cyclone
Basic Principles of Radar-based Rainfall Nowcast

- Dynamic radar-raingauge rainfall calibration
- Remote-sensing
- Storm tracking
- Time integration (Semi-Lagrangian advection)
SWIRLS Echo Motion Viewer
SWIRLS F/C Rainfall Viewer

May 9, 2005, 12:12 PM
1 hr Forecast based on TMS Radar

Radar nowcast

Nowcast and NWP blended
## HKO’s Mesoscale Data Analysis System - LAPS

| **Horizontal Resolution** | 10 km (TC applications)  
5 km, 1.5 km and 500 m (Nowcast) |
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<thead>
<tr>
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<tbody>
<tr>
<td><strong>Update frequency</strong></td>
<td>Hourly</td>
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</table>
| **Data ingested**         | SYNOP, SHIP, BUOY  
AWS data from Hong Kong and Guangdong;  
Radiosonde;  
Wind profiler;  
Aircraft (AMDA);  
Satellites (FY-2C/MTSAT)  
Radar (reflectivity and Doppler velocity) |
| **Model background**       | HKO-RSM (20 km resolution)  
NHM (5 km resolution) |
| **Computer platforms**    | IBM SP / Linux PC |
HKO-LAPS Domain (1)

- TC-LAPS
  - 10 km resolution
  - Mesoscale analysis over southern China and South China Sea
  - Nowcast of wind/pressure at selected stations in HK during TC situations
LAPS Domains (2)

- **GD-LAPS**
  - 5 km resolution
  - Mesoscale analysis over Guangdong
  - Initialize moisture variables in NHM
  - Input to SWIRLS lightning nowcast

- **PRD-LAPS**
  - 1.5 km resolution
  - 241x241; 45 pressure levels
  - Mesoscale analysis over the Pearl River Delta

- **HK-LAPS**
  - 500 m resolution
  - 169x135; 45 pressure levels
  - Local scale analysis
Data flow in LAPS

Model forecast ORSM, MPI-RSM, NHM

- SYNOPS
- HK/GD AWS
- WP/RASS
- radiosonde
- GPS
- Radar dBZ
- Doppler wind
- FY2C/MTSAT
- Satellite sounding
- TREC wind
- AMDAR/PIREP

- lga

- surface
  - background
  - Surface wind, pp, temp, RH

- wind
  - 3D wind

- temp
  - 3D temp

- cloud
  - Cloud cover, 3D RH, cloud water
  - q_l, q_i, q_s, q_r, q_h

- moisture
  - Balanced 3D u,v,w, f

- balance

- lapsprep
  - Initial data for NHM

- NHM Hot Start
Application of LAPS in mesoscale analysis

- **LAPS Hourly Analysis**
  - an integrated platform to digest all available observation data (AWS, radar ..) to monitor mesoscale weather systems
  - analyse and diagnose mesoscale circulation in rapidly-update cycle
  - High resolution:
    - 5 km/1.5 km and 500 m horizontal resolution
    - Initialization of cloud hydrometeor fields in non-hydrostatic NWP model (HKO-NHM)
LAPS Hourly Analysis
On Trial ver 2000-04, based on laps 05-15

Analysis time (UTC): 2000000000

Next update: Analysis time 7+55 min.

Domain (Resolution) normal zoom
GD 5km normal
PRD 1.5km normal
Hong Kong 500m normal

Surface
Wind
Wind+Temp.
Wind+LTEC

Upper levels
Wind-RH
325hPa
350hPa
700hPa
500hPa

Instability and moisture analyses
K Index
Lifted Index
Total Totals Index
Total Precip. Water

Descriptions of Stability Indices

Link to LAPSTC Nowcast

LAPS 5km surface wind and temp.
12/6/2008 09UTC 12/6/2008 17HKT

deg Celsius
40
35
30
25
20
15
10
5

112°E 113°E 114°E 115°E 116°E 117°E
Current NWP Systems in HKO

60-km ORSM (Operational Regional Spectral Model) 9S-59 N, 65-152 E

20-km ORSM 10-35 N, 100-128 E

5-km NHM (Non-Hydrostatic Model)
## Main Applications

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<th>ORSM</th>
<th>NHM</th>
<th>WRF</th>
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<td>Others</td>
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<td>Research and specialized meteorological support</td>
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Non-hydrostatic Model – NHM

- 5-km horizontal resolution
  - 121x121 grid-points,
  - 45 vertical levels (lowest at 10m)

- Initial condition:
  - 20-km ORSM + LAPS moisture analysis

- Boundary: 20-km ORSM

- KF + cloud microphysics

- Hourly update

- Provides 12-hour forecast
Operation of 5km NHM

- IBM p690
- 2 nodes, 32 Power 4 processors @1.1 GHz
- 48 GB memory
- Peak performance 141 GFLOPS
RAPIDS – Rainstorm Analysis and Prediction Integrated Data-processing System

- Application of NHM in very short-range precipitation prediction ⇒ NWP-Nowcast Blending
  - Nowcasting component – SWIRLS
    - 1 - 6 hr QPF by extending the linear extrapolation of radar echoes
  - NWP component – Non-hydrostatic Model (NHM)
    - 1 – 6 hr QPF by non-hydrostatic numerical model

- 2 km resolution
- T+1 to T + 6 hour forecast
SWIRLS NHM Radar-based nowcasting system; extrapolation effective in advective cases

Guidance on dynamic evolution of precipitation systems in rapidly changing cases


RAPIDSRAPIDS high resolution, rapidly updated very-short-range QPF

Figure 1. Schematic representation of the loss of information content in forecasts as a function of lead time. The solid line represents the theoretical limit of predictability. The dashed line represents NWP models and the dotted line nowcasting methods.
Data flow of QPF blending in RAPIDS

Rainfall forecast using 5 km NHM →

Downscaled to 2-km grid using interpolation →

re-located rainfall distribution →

Weight of NHM forecast in blending →

6 hr forecast of rainfall using SWIRLS semi-Lagrangian advection scheme based on TREC analysis

Radar 128 km range ~0.5 km resolution →

Up-scaled to 2-km grid using grid-averaging →

2004 05 08 08:00 HKT

6 hr RAPIDS rainfall forecast
SPIDASS - SWIRLS Integrated Warning Panel

Real-time alert status auto-updated at 01:30 AM 20090604

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Legend (Note: The following alerts apply to the Hong Kong domain only. Click on the status icons above to see the affected locations.)

- **Rainfall ≥ 20 mm in 1 hour or 40 mm in 3 hours**
- **Hourly rainfall ≥ 20 mm, ending at 1-hour interval**
- **Flood threat in northern NT**
- **Landing threat**
- **Severe gust threat (storm force 10)**
- **Strongest gust threat (storm force 12)**
- **High chance of severe thunderstorms in the next 3 hours**
- **Halley threat (very rare)**
- **Lightning threat (severely severe), i.e., CG strikes less than 10 per minute**
- **Lightning threat (severely severe), i.e., CG strikes between 10 and 100 per minute**
- **Lightning threat (severely severe), i.e., CG strikes more than 100 per minute**
- **Thunderstorm threat (reflectivity ≥ 40 DBZ)**

Product names & underlying algorithms
Tropical Cyclone Information Processing System - TIPS
Meteorological Information Dissemination System - MINDS

Warnings, forecasts and Observational Bulletins

- Leased line circuits
- SMS
- Email
- Public Websites
- Fax
- IVRS telephone system
Main Features of MINDS

• 2nd Generation – fully operational since Jan 2009
• 3-Tier Design: Client + Application Server + Database
• Data stored in XML format
• Support Work Flow
• Support Role
• Automatically bring up “tasks-to-do” to users when:
  – warnings criteria/thresholds reached/departed;
  – Tropical Cyclones entering/leaving Area of Responsibility;
  – issuance/cancellation of warnings.
MINDS User Interface

Roles

Warnings in force

Warning bulletin preparation wizards

Tasks-to-do
Upgrade GTS DBMS
HKO MINDS DBMS
Conclusions

• MINDS database
  – Use RAC for high availability (a mission-critical system for public weather service operating round the clock with little tolerance in down time)
  – Use RAC for high scalability (choose a scalable storage system)

• GTS, AWS, Rainguage databases
  – Use Data Guard to improve availability (no shared disk device needed)
  – Deploy active standby database for read-only access to offload primary database
Thank you