WMO Aviation Research Demonstration Project (AvRDP) and Seamless Trajectory Based Operation (TBO)

PW Peter Li
Hong Kong Observatory
Chair, AvRDP SSC
New Era of Aviation Industry

- WMO Congress XVI recognized that these changes could pose significant challenges to WMO Members, as well as provide new opportunities.

<table>
<thead>
<tr>
<th>WMO STRATEGIC PRIORITIES</th>
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<td>1. Disaster risk reduction</td>
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<td>2. Global Framework for Climate Services</td>
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<td>3. WMO Integrated Global Observing System</td>
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<td>4. Aviation meteorological services</td>
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<td>5. Polar and high-mountain regions</td>
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<td>6. Capacity development</td>
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<td>7. Governance</td>
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Aviation meteorological services: One of the 7 priorities in 2016-2019
Recommendation 2/10 — Development of meteorological service for the terminal area

That ICAO, in close coordination with WMO, be tasked to:

a) include meteorological service for the terminal area and other relevant operational requirements in Block I and subsequent blocks of the aviation system block upgrade methodology to highlight potential related impacts on air traffic flow in consideration of air traffic control and air traffic management (ATM);

b) develop ATM-tailored meteorological service for the terminal area to meet future ATM requirements identified by the Global Air Navigation Plan (Doc 9750) and reflect the appropriate functional and performance requirements in the relevant provisions, noting outcomes from ICAO expert groups on meteorology, ATM and flight operations;

c) develop guidance on verification methodology toward the continuous improvement of meteorological information to ATM; and

d) integrate the information concerning meteorological service for the terminal area into the future system-wide information management environment underpinning the future globally interoperable ATM system.
AvRDP Objectives

A joint effort between CAS and CAeM, in 5 years (2015-2019)

• **Phase I (MET Capability enhancement):** to conduct research in **nowcasting and mesoscale modelling** at a number of **international airports** located in Northern and Southern Hemisphere with a view to supporting the development of the next generation aviation initiative, the Aviation System Block Upgrade (ASBU) under the new Global Aviation Navigation Plan (GANP) of International Civil Aviation Organization (ICAO). Key concepts under ASBU are the development of seamless **Trajectory-Based-Operation (TBO, or “gate-to-gate”)** focusing the **Meteorological Services to ATM (MSTA)** near airport **terminal** area.

• **Phase II (MET-ATM translation)** to collaborate with the respective Air Traffic Management (ATM) to **translate** the Meteorological (MET) information into ATM Impact products so as to **demonstrate the benefits** of the MET information (nowcast and mesoscale modelling) in the aviation industry;

• **Capacity Building** to help in **capacity building** via the knowledge gained in AvRDP other WMO Members who need to enhance their aviation MET services so as to meet the ASBU initiative.

* Not just enhancing flight efficiency but also safety and environment-friendly by optimizing trajectory and hence reducing fuel waste
Seamless Trajectory-Based Operation (TBO)

Seamless nowcasting -> mesoscale -> global scale -> mesoscale -> nowcasting scale

Mesoscale / Global modelling

En Route Phase:
Mainly supported by global model

Terminal Control Area:
Location specific

Traffic Flow Management

Terminal Control Area:
Location specific

MSTA
The closer to the Terminal Control Area/Aerodrome, the finer/most updated weather information required.

~ 6 hours flight radius

Meteorological Service for the Terminal Area (MSTA)

Spatial resolution $\Delta x$ from 10’s km to sub-km
Temporal resolution $\Delta t$ from hours to minutes

Update frequency from hours to minutes
# Initially 6 AvRDP Airports

<table>
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<tr>
<th>AvRDP Airport</th>
<th>Climatological regime</th>
<th>Weather elements to be studied in AvRDP</th>
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</table>
| Charles de Gaulle Airport (CDG) | Mid-latitude in Northern Hemisphere  
Location: Inland | Winter weather – snowfall, icing, low temperature  
Fog |
| Hong Kong International Airport (HKG) | Subtropical in Northern Hemisphere  
Location: Surrounded by water  
Next to high mountain | Convection and Thunderstorm  
Low visibility and ceiling |
| O.R. Tambo International Airport (Johannesburg Airport) (JNB) | Subtropical in Southern Hemisphere  
Location: Inland | Convection  
Fog |
| Shanghai Hongqiao Airport (SHA) | Subtropical/mid-latitude in Northern Hemisphere  
Location: Inland not far away from River Estuary and East China Sea | Convective weather |
| Toronto Pearson International Airport (YYZ) and Iqaluit Airport (YFB) | Mid-latitude in Northern Hemisphere  
Location: Inland but not far away from Lake  
High-latitude in Northern Hemisphere  
Location: On Frobisher Bay | Winter weather – snowfall, icing, precipitation type and amount, visibility, wind speed, direction shear, and gust, turbulence, and low ceilings  
Convective Weather  
Artic weather – Winds, blowing snow, fog, visibility, ceiling |
Blending LE with mesoscale model

- 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
- Dynamic-weighting
Seamless convection within terminal area

Blended nowcasting and non-hydrostatic model to forecast 0 to 6 hrs ahead

Flight/route specific convection nowcast

0-1 hr nowcast

Weather radar overlaid with lightning

Satellite animation

3 hrly forecasts based on global model

0-6 hr blended nowcast over various significant areas
AvRDP IOP I, II, III data, including Airport Observations, Nowcasting facility, modelling facility and ATM data (HKG)

<table>
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<tr>
<th>Airport</th>
<th>Observations</th>
<th>Nowcasting system and model</th>
<th>ATM data</th>
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<tbody>
<tr>
<td>HKG</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
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</table>

- Weather Radar (conventional or Doppler), Geostationary Satellite
- Wind profiler
- LIDAR
- Anemometer
- Visibility sensor
- AMDAR/ACARS data
- Other observations
- Global lightning (since mid 2016)
- Nowcasting system
- Micro/mesoscale NWP
- Regional model
- PIREP
- Aircraft data (including QAR)
- ATM capacity data
- Air traffic data
- ADS-B (since 2016)
Phase II: Translate MET information into ATM Impact

- Airport Capacity in network operation
- Airspace Capacity
- Arrival/Departure Delay
- Aircraft de-icing, runway clearance, engine icing in freezing fog
- Lightning strike affecting ground ops.
ATM Impact Parameter (1) – airport capacity reduction - HKG

MET-ATM Integrated Monitoring [Trial]

Hourly airport arrival and departure rate

Significant echo coverage percentage

Reduction of AAR as a function of echo density within the approach airspace
ADS-B collected (for Phase II)

ABS-B (aircraft position) overlaid with weather radar and satellite
ATM Impact Parameter (2) – airspace capacity
Refining flight avoidance probability

Deviation and Missed approach

Impact thresholds

Probability of avoidance

Looping and missed approach

Airspace capacity

+ Trajectory Based SigConv F/C

+ Flight trajectory
ATM Impact Parameter (3) – airspace capacity reduction - HKG

0-6hr blended nowcast over various significant areas

Satellite animation

3 hrly forecasts based on global model

Airport Capacity Notification sent to regional airports
Capacity Validation quantification (preliminary)

- 2015 data for training, 2016 data for validation
- General trend matched well, but ...
- ADR over-estimates the reduction in confined weather condition
- ADR under-estimates in more extensive weather condition
- Need further study
The simulation would be useful for ATC to optimize the sequencing, reduce unnecessary holding, shorten the delay and reduce the waste of fuel to protect the environment.
Summary

• The blended nowcasting and mesoscale model information bring positive impact to ATM operations in the terminal area.

• Close collaboration is essential to translate the MET information into ATM impacting parameters for their decision making, e.g., defining the thresholds of the radar reflectivity for alerting levels.

• The project is also tasked to help capacity building - next year will have the 2nd Training Workshop focusing on MET-ATM translation.

• So far, AvRDP focuses on terminal area. EC 68 has decided to expand the project into a larger scale Aviation Research Project. How AvRDP would be evolved would also be shaped by the outcomes from this Conference.
Ultimate TBO something like this?

- Seamlessly combining MSTA with En-route Forecast
- Uplinked MSAT information
### AvRDP SSC Membership

<table>
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<tr>
<th>Name</th>
<th>Representation</th>
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<tr>
<td>Peter Li, Chair</td>
<td>HKO rep of CAeM</td>
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<tr>
<td>Erik BECKER</td>
<td>SAWS rep of JNB</td>
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<tr>
<td>Janti REID</td>
<td>ECCC rep of YYZ &amp; YFB</td>
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<tr>
<td>Stephanie DESBIOS</td>
<td>MeteoFrance rep of CDG</td>
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<tr>
<td>Fengyun WANG</td>
<td>CAAC rep of SHA</td>
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<td>Sharon LAU</td>
<td>HKO rep of HKG</td>
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<tr>
<td>Peter M. CHADWICK</td>
<td>CAD rep of HKG (ATM expert)</td>
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<td>Baode CHEN</td>
<td>SMS rep of CMA</td>
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<tr>
<td>Matt Strahan</td>
<td>NOAA rep of NextGen</td>
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<tr>
<td>Stefane BELAIR</td>
<td>ECCC rep of NMRWG</td>
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<tr>
<td>Barbara Brown</td>
<td>NCAR rep of JWGFVR</td>
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<tr>
<td>Herbert PUEPEL</td>
<td>Ex-WMO C/AeM and AustroControl</td>
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<tr>
<td>Dennis HART</td>
<td>EuroControl rep of SESAR (Phase II)</td>
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**AvRDP Website** ([https://avrdp.hko.gov.hk](https://avrdp.hko.gov.hk))

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**Mission**

The overall mission of the AvRDP is to, through international collaboration, develop, demonstrate and quantify the benefits of end-to-end nowcasting aviation weather services for the terminal area focused on high impact weather. The AvRDP will focus on nowcasting aviation weather, including the respective uncertainty/confidence estimation, over the Terminal Control Area for the next 0-8hr. For simplicity, nowcast or nowcasting hereafter refers to all techniques/systems including observation-based, expert system-based, human-machine interfaced and meso/microscale NWP or any combination thereof which can generate high resolution, rapidly updated forecasts for the next 0-8hr ahead. This definition of nowcast(nowcasting is in accordance with the definition/practice adopted in WWRP and the nowcasting community.
Thank You