Science Plan
Aviation Research Demonstration Project (AvRDP)
- a joint project between CAS and CAeM

(v.4, Adopted by AvRDP SSC, November 2017)

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1. Introduction

1.1 New Global Aviation Navigation Plan

The CAS/WWRP/Working Group on Nowcasting Research (WGNR) has organized several Research and Development Projects (RDP) with great success in the past years, mostly concerned with the Olympic Games, for advancing nowcasting and mesoscale modelling sciences. During the joint meeting of the WGNR and CAS/WWRP/Working Group on Mesoscale Weather Forecasting Research (WGMWF) held on 11-13 August 2012 in Rio de Janeiro, Brazil, a proposal was put forth to set up an aviation specific Research Demonstration Project (hereafter AvRDP) at several airports in different climatological locations.

The purpose of the AvRDP is to demonstrate the capability of nowcasting and mesoscale modelling techniques in support of the development of the next generation aviation initiative, namely, the Aviation System Block Upgrade (ASBU) under the new Global Aviation Navigation Plan (GANP) which was endorsed by ICAO in 2013. In the ASBU roadmap, aviation MET services will be required to provide enhanced services to be phased in during the next 15+ years, namely Block 1 by 2018-2023 (B1-AMET), Block 2 by 2023-2028 (B2-AMET)[1] and Block 3 by 2028 and beyond (B3-AMET). The key concept in ASBU is the Trajectory Based Operation (TBO) which would integrate seamlessly high-resolution, rapidly-updated observation, nowcast and forecast along the entire flight trajectory, from take-off, ascending, en-route, descending and to landing phases, into the air traffic management (ATM) system (Fig.1). The meteorological elements concerned in the TBO include, amongst others, convection and thunderstorm, ceiling and visibility, wind, windshear, upper-air and low-level turbulence, in-flight icing, winter weather, surface icing and airframe icing, tropical cyclone, wake vortex, volcanic ash, radiative cloud and space weather. The current, emerging and foreseen MET capabilities for aviation weather have been outlined by WMO/CAeM ET M&M in collaboration with ICAO the draft of which can be found in Appendix A and B. AvRDP is aimed at providing a more thorough assessment of the above-mentioned MET capability and demonstrate its benefits to the aviation community in support of the ASBU initiative.

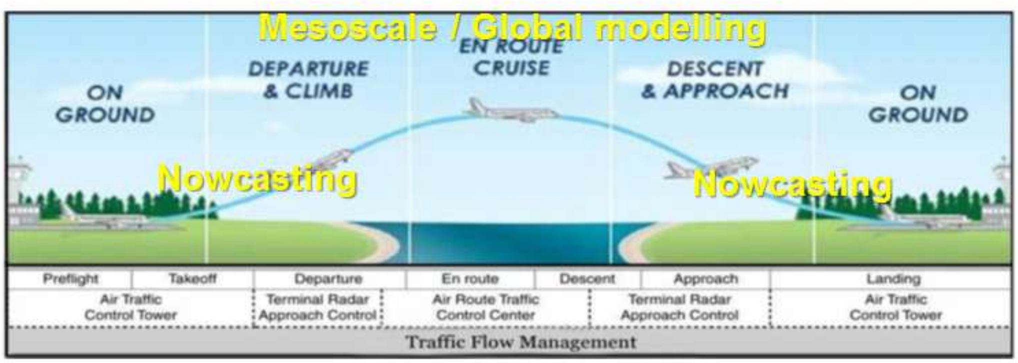


Fig.1 Seamless meteorological information required under the Trajectory Based Operation (TBO) concept

1.2 Trajectory Based Operation and Meteorological Services for Terminal Area

Under the TBO concept, seamlessly blending of actual observation, nowcasting, mesoscale numerical weather prediction (NWP) model and harmonized global numerical weather prediction model will be required for the take-off/landing, ascending/descending and en-route phases. The global weather prediction data required could be provided by the enhanced World Area Forecast System (WAFS) or other global models (ICAO/WMO, 2014a). The nowcast and mesoscale weather forecast data required,

1 To be included in the next edition of GANP.

however, would need to be provided by the regional or local aviation meteorological authority.

On the development of TBO, the ICAO/WMO Conjoint Meeting held in July 2014 (ICAO/WMO 2014a) recommended ICAO to collaborate closely with WMO to develop Meteorological Services for Terminal Area (MSTA) to focus on the short-term nowcasting services over the Terminal Area; establish the functional and performance requirements; develop guidance on verification for continuous improvement; as well as integrate the MSTA into the future global aviation System Wide Information Management (SWIM).

MSTA focuses on nowcasting services from 0-6 hours within the Terminal Control Area (TCA) of each airport (Fig.2). The closer to the airport, the finer temporal and spatial resolution as well as faster updated weather information will be required.

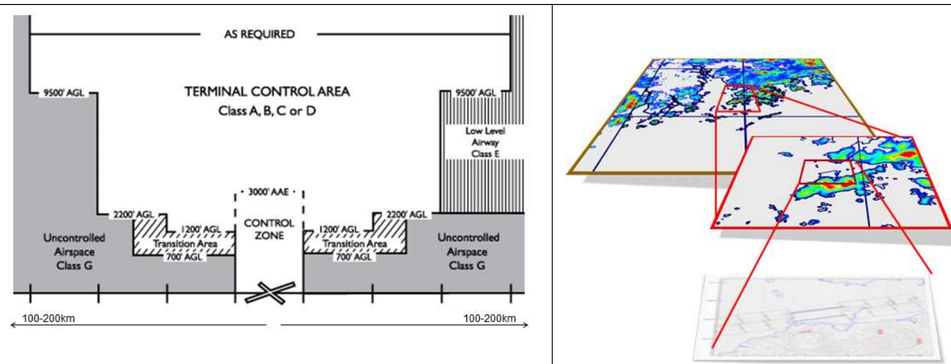


Fig.2 MSTA covering area: Terminal Control Area of the airport. The closer to the airport, the high resolution meteorological information will be required.

During the aforesaid meeting in Rio de Janeiro, a subgroup was tasked to make a proposal for setting up the AvRDP. The subgroup was established by members of WGNR, WGMWFR, NCAR, etc. with representatives from Canada, China, France, Hong Kong, China, Japan, Netherlands and USA. The main tasks of the subgroup are to define the scope of the AvRDP, identify airports suitable for hosting the AvRDP and develop the proposal for WWRP's endorsement. The AvRDP initiative was also brought up by CAeM during the Management Group Meeting held in November 2013 (CAeM/MG-2013). It was welcomed by the ICAO/WMO Conjoint Meeting held in Montreal, Canada, on 7-18 July 2014. The Commission of Atmospheric Science (CAS) agreed to offer help to bring this project forward under the WWRP RDP framework. The initiative was also brought up at the Commission for Basic Systems Ext (2014) meeting. Apart from showing support, the meeting considered its possible involvement for integration of the initiative into an operational component to enhance service delivery following a successful demonstration of capability.

1.3 Objectives of the AvRDP

The AvRDP will preliminarily focus on a number of scientific questions:

- What is the current state-of-art nowcasting and mesoscale modelling techniques applicable for MSTA? In other words, what is the gap between the current MET capability and the expected MET capability in ASBU?
- What nowcasting techniques could further be developed to support MSTA in the near-term timeframe?
- What would be the suitable aviation nowcasting and modelling methodologies, deterministic and probabilistic, for meeting the ASBU requirements?
- How to evaluate the performance of aviation nowcast/forecast products for continuous improvement monitoring?

- What methodologies to transfer to WMO Members for enhancing their capability for the provision of MSTA including the interaction withTBO to meet the ASBU requirements?

The AvRDP aims at a more systematic study of these questions in different airports with different climatology and air transport density.

Well before the endorsement of the GANP, several MET offices/MWOs have already developed specific nowcasting systems or mesoscale NWP models to address the local users' needs beyond ICAO Annex 3 requirements. Examples of some available nowcasting/forecasting products/services can be found on the CAeM ET/M&M MSTA demonstration webpage http://www.msta.weather.gov.hk/demo_projects/demo_projects.phtml (Fig.4). More nowcasting/modelling systems developed in recent years are briefly described in section 2.5 below.

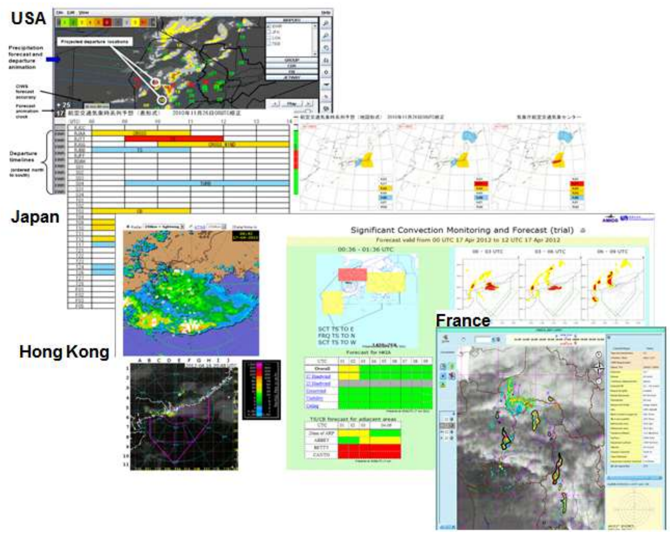


Fig.3 A few examples illustrating the international trend in nowcasting/modelling development to address new aviation needs.

Apart from the above MET research, the AvRDP will also address on a number of operational issues:

- How to <u>translate</u> the MET nowcast/forecast products into aviation impact?
- How to <u>integrate</u> the MET information, including <u>uncertainty</u>/confidence information, into ATM operation/decision?
- How to <u>quantify</u> the benefits of the new MET information from ATM perspective?
- Which type of new MET information should be included as standard or recommended practices for high density airports in future updates to ICAO Annex 3 or PANS-MET?

2. Scope of the AvRDP

2.1 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 0-6hr. **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 0-6hr ahead. This definition of nowcast/nowcasting is in accordance with the definition/practice adopted in WWRP and the nowcasting community.

2.2 Phases

Due to the complexity of ASBU and the vast differences in the MET functional requirements at different airports, it is not feasible for the AvRDP to deal with all the weather elements at all the airports at the same time. To take a more practical approach, the AvRDP will be conducted in two Phases:

(i) Phases I will focus on the MET capability research on some weather elements which are commonly considered to bring significant impacts to high density airport/airspace, such as convection, winter weather, wind change, low visibility and ceiling, etc., depending on each airport's characteristics. Phase I will be conducted from summer 2015 till summer 2017. Each AvRDP Airport will collect MET data, conduct nowcast/modelling during their respective Intense Observation Period (IOP) and conduct verification during the following research period. The data collected during the IOP will be shared with other AvRDP Participants who would use the data to implement their advanced nowcasting and/or short-range mesoscale models over the AvRDP Airports so as to demonstrate the state-of-art aviation MET capability for generating the MSTA products. Depending on their readiness (such as funding arrangement, etc.), some Airports/Participants may start the project earlier while some may start later. The preliminary findings of Phase I will be reported and discussed in mid 2016. A Phase I report is expected to be delivered by mid 2017 to summarize findings from Phase I. Meanwhile, a capacity building training workshop focusing on the enhancement of MET capability will be conducted within Phase I to share relevant technologies and capabilities with other WMO MET offices/MWOs whose aviation nowcasting/modelling capabilities need to be enhanced so as to meet the ASBU requirements.

(ii) Following the completion of Phase I, the AvRDP Airports may enter Phase II. Phase II will focus on the translation of MET information into ATM-specific parameters and the associated ATM impact validation. All AvRDP Airports participating in Phase I are expected, though not compulsory, to participate also in Phase II by working closely with their local ATM authority/service provider to conduct the MET-ATM translation and validation. The exact time frame and duration of Phase II will depend on the progress of each AvRDP Airport in Phase I but the preliminary schedule will be mid 2016 (the earliest) or mid 2017 (the latest) till end 2018.

It is noted that there are a few overarching initiatives being conducted especially NextGen and SESAR. However, these two initiatives are limited to USA and EU respectively. The WMO AvRDP aims to address the aviation needs of WMO Members, especially those lacking aviation nowcasting and/or mesoscale modelling technology in order to meet the future ASBU requirement. The AvRDP will keep a balance with the NextGen and SESAR so as to avoid overlap and/or competition. Experts from these two initiatives would be invited to join the management group of AvRDP to provide updated information about the two initiatives. The findings in the AvRDP may also be useful in defining the MET functional and performance requirements in the future ICAO TBO- related document which would provide recommendations on needed development of the next generation meteorological services in support of the GANP envisioned under B1-AMET till B3-AMET.

2.3 Components

The AvRDP will be conducted in a number of selected airports (hereafter AvRDP Airports) representing a range of typical weather affecting aviation operations globally, e.g. low latitude airports affected by subtropical weather especially significant convection, high latitude airports affected by winter weather, low visibility and ceiling conditions, etc. Observations/nowcasts will be made during the Intensive Observation Periods (IOPs) which will be carefully selected for the collection of high density meteorological observations for executing the nowcast, either by the participating airport and/or by other nowcast organizations (hereafter AvRDP Participants) who would implement their nowcasting system over the AvRDP Airports. There is no limit to the number of airports an AvRDP Participant may choose to implement a nowcasting system, and the hope is that identical systems may be run at multiple airports. This is particularly useful for identifying variations of the predictability of different aviation weather in different climatological locales. Besides MET observations, the AvRDP Airport will also be required to collect PIREP, aircraft data, and ATM data as far as possible for the verification and validation of the performance of the nowcasting MET products in order to illustrate the benefits of the MET services in support of ATM operations. As such, the AvRDP Airport will need to coordinate with local ATM folks to determine how to translate the MET information into ATM impact and what would be the most appropriate parameters for evaluating the performance from an ATM perspective in Phase II of the project. It is understandable that not all AvRDP Airports would be able to establish this coordination with the local ATM authority in a short period of time and hence, it is not required that all AvRDP Airports commit to Phase II. An Evaluation Team under the AvRDP Science Steering Committee (ASSC), in close collaboration with ATM experts, will be formed to provide guidance in performing the verification and validation.

By the nature of RDP, no real-time component will be required in this project. The researches in Phase I and II can be conducted using past data (collected during the IOPs), post-analysis, simulator and etc.

The AvRDP will contain the following Components:

(A) Nowcasting Component

This component focuses on the various nowcasting techniques, existing or novel, including but not limited to the following types:

(i) Radar-based nowcasting system or satellite-based nowcasting system, including human-machine interfaced and expert system-based system;
(ii) Convection-resolving mesoscale or microscale NWP model;
(iii) Blending of observations with high resolution NWP model;
(iv) Blending of radar/satellite-based nowcasting products with NWP system; and
(v) Ensemble/probabilistic nowcasting product.

(B) Verification Component

This component is essential to assess the performance skill of the nowcasting techniques adopted at the AvRDP Airports. The evaluation will also focus on what would be the most suitable verification method for deterministic and probabilistic aviation nowcasting products. Apart from the conventional verification matrix for MET products, metrics will also be evaluated for measuring ATM impacts (see subsection (C) below). The major outcome from the verification component is a proposed suite of methodologies/schemes to be used in future MSTA/TBO services for continuously monitoring the performance and identification of opportunities for future improvement.

(C) Impact and validation Component

This component will study how to translate the nowcast products into ATM impact. Examples include translation of the convection coverage/intensity to airport/runway/airspace capacity or aircraft delay time. Representatives from local ATM or airline will be involved to provide expert advice on this component. By involving ATM/airline experts, the project could validate whether such information meets the needs of ATM and evaluate directly the benefits of the integrated MET-ATM information to the end users (ICAO/WMO 2014b). This component is an important part of the project as illustrated in Fig.4 (ICAO/WMO 2014a) where the MET information is translated and integrated into the ATM system for decision making at the end of the whole process.

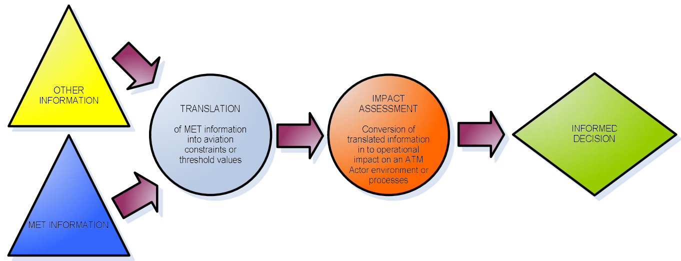


Fig. 4 Integration between MET and ATM for decision making.

(D) Capacity Building Component

The AvRDP will include a couple of training workshops that include lectures, demonstration and hands-on training activities geared toward capacity building and ultimately technology transfer. The aim is to enable WMO Members enhancing their aviation weather services in order to meet the ASBU requirements.

The lectures are envisioned as exchanges of information within and between the weather and aviation communities with the goal of enhancing nowcasting technology, communication and collaborations on MSTA/TBO related matters. These activities may be focused on a particular airport to discuss specific needs and capabilities or more broadly to foster a dialogue between the weather and aviation research and operational communities. Demonstration and hands-on workshops may be conducted to serve the training of personnel in the use of particular weather and weather-impact prediction tools. These workshops will enable WMO Members to familiarize themselves with emerging capabilities and develop relationships toward transferring those capabilities and techniques. The demonstrations may also be geared towards showcasing the benefits of new or enhanced capabilities of nowcasting weather and weather impacts on aviation operations. The technology transfer of new capabilities ultimately requires a dedicated multi-year and collaborative effort in order to be successful. The goal is to empower the receiving partner such that they can operate and maintain the new technology in their operational environment and better serve their aviation clients.

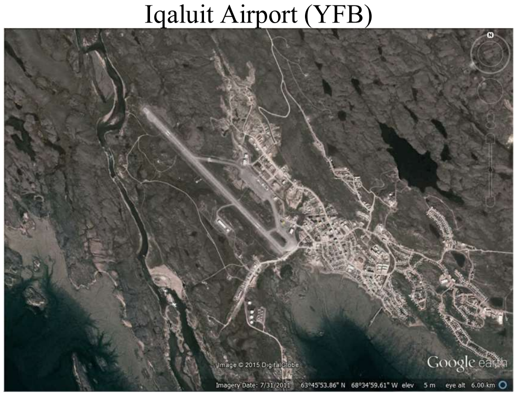
Details on the training programme are to be developed in due course.

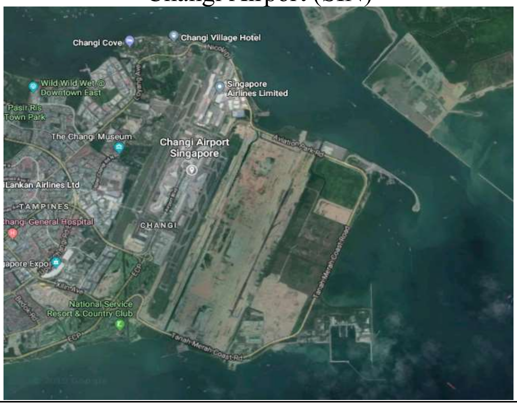
2.4 AvRDP Airports and the associated weather elements

The AvRDP will focus on high density airports at various climatological locales. High density airports are focused in this project as the air traffic over them is more vulnerable to weather than that over low density airports. For the sake of demonstrating advanced MET capabilities, the airports participating in the AvRDP should be equipped with advanced observations especially remote sensing observations (e.g., radar and/or satellite, etc.), nowcasting facility, mesoscale modelling system/data, and preferably ATM data such as PIREP, airport capacity data, air traffic data, aircraft data, etc. to enable and support relevant verification and impact studies.

Initially, the following AvRDP Airports as well as their associated weather elements to be studied are identified for participating in Phase I (details of the observational platform and nowcasting/modelling facilities available in the respective airport are listed in Appendix C):

AvRDP Airport	Climatological regime	Weather elements to be studied in AvRDP
Charles de Gaulle (CDG) 	Mid-latitude in Northern Hemisphere 49° 00′ 35″ N 02° 32′ 52″ W Runways: 08L/26R 08R/26L 09L/27R 09R/27L Location: Inland	Winter weather - snowfall, icing, low temperature Fog
Hong Kong International Airport (HKG) 	Subtropical in Northern Hemisphere 22° 18′ 32″ N 113° 54′ 52″ E Runways: 07L/25R 07R/25L Location: Surrounded by water Next to high mountain	Convection and Thunderstorm
O.R. Tambo International Airport (Johannesburg Airport) (JNB) 	Subtropical in Southern Hemisphere 22° 08′ 21″ S 28° 14′ 46″ E Runways: 03L/21R 03R/21L Location: Inland	Convection Fog

Shanghai Hongqiao Airport (SHA) 	Subtropical/mid-latitude in Northern Hemisphere 31° 11′ 53″ N 121° 20′ 11″ E Runways: 18L/36R 18R/36L Location: Inland not far away from River Estuary and East China Sea	Convective weather
Toronto Pearson International Airport (YYZ) 	Mid-latitude in Northern Hemisphere 43° 40′ 36″ N 79° 37′ 50″ W Runways: 05/23 15L/33R 15R/33L 06L/24R 06R/24L Location: Inland but not far away from Lake	Winter weather – snowfall, icing, precipitation type and amount, visibility, wind speed, direction shear, and gust, turbulence, and low ceilings Convective Weather
Iqaluit Airport (YFB) 	High-latitude in Northern Hemisphere 63˚45’23’’N 68˚33’21’’W Runways: 17/35 Location: On Frobisher Bay	Arctic weather – Winds, blowing snow, fog, visibility, ceiling

Changi Airport (SIN)  	Tropics 01°21’33.16” N103°59’21.5”E 2 Runways: 02/20 Location: Coastal	Convective Thunderstorm
Pulkovo Aiport (LED)  	Mid-latitude in Northern Hemisphere 59° 48′ N 30° 15′ E 2 Runways: 10/28 Location: Inland but between 2 Lake	Visibility and Cloud Ceiling
Indira Gandhi International Airport (IGI) 	Subtropic in Northern Hemisphere 28°34’07’’N 77°06’44’’E 3 Runways: 09/27 10/28 11/29 Location: Inland	Summer Convection Winter Fog/Low VIS
Tokyo Airport (Narita/Haneda Airport) 	Subtropic in Northern Hemisphere 35°45’55’’N 140°23’08’’E 2 Runways: 16/34 Near shore	Summer Convection A/P TS, Low VIS, Cloud ceiling winds ATC Sectors Convection Low level winds

2.5 AvRDP Participants

AvRDP Participants refer to those nowcasting experts who will utilize the observational data and/or modelling data offered by the AvRDP Airports during the IOPs to execute their own nowcasting systems to generate nowcast products for the AvRDP Airports. AvRDP Participants normally have been operating advanced nowcasting system which can be relocated to other airports to generate nowcasting products for the respective TCA. Depending on the characteristics of the Participants' nowcasting systems, they can choose to execute their system for one or multiple AvRDP Airports and can choose whichever weather elements they wish to demonstrate. The types of systems with aviation applications to be demonstrated may include (with a few examples):

- Observation-based nowcasting systems -
  e.g. ATNS (Aviation Thunderstorm Nowcasting System, HKO),
  ASPOC (Thunderstorm alerting and Nowcasting system for ATM, Meteo-France)
  ATSAS (Automated Thunderstorm Alert Service, BoM),
  INSITE (INtegrated Support for Impacted air-Traffic Environment, FAA),
  EUMETSAT SAFNWC RDT (Rapid Development Thunderstorm, EUMETSAT)
  GOES Global Lightning (NASA)

- Nowcasting and very-short-range forecasting systems based on high-resolution NWP models,
  e.g. AROME-France and AROME-Aeroport (Meteo-France),
  AVM (Aviation Model, HKO),
  CoSPA (Collaborative Storm Prediction for Aviation, ESRL, NCAR and MIT/LL)
  HRRR (High Resolution Rapid Refresh, NOAA)
  UKV/Nowcast (UK MetOffice),
  GRAPES (Global and Regional Assimilation and Prediction System, CMA)

- Nowcasting and very-short-range forecasting systems based on blending NWP and nowcasting techniques -
  e.g. CAN-NOW (Canadian Airport Nowcasting System, EC),
  INCA-CE (Integrated Nowcasting through Comprehensive Analysis – Central Europe, ZAMG)
  RAPIDS (Rainstorm Analysis and Prediction Integrated Data-processing System, HKO)

- Human-machine interactive systems -
  e.g. AutoNowcaster (NCAR)
  cdm@cdg (Met Information Service for CDM at CDG, Meteo-France)
  iCAST (interactive Convective Analysis and Storm Tracking, EC)
  TDA (Tactical Decision Aids for Aviation, NOAA)

The above list is by no mean complete and could be extended with time.

Apart from running nowcast for its own Airport, an AvRDP Participant can also implement its nowcast/mesoscale model at any of the AvRDP Airports to demonstrate the state-of-air nowcasting technology. A template indicating how the AvRDP Participants could participate in other AvRDP Airports is illustrated below (*subject to change by the AvRDP Participants after coordination with the AvRDP Airports*):

AvRDP Participant	AvRDP Airport						MET elements		
	HKG	JNB	CDG	SHA	YYZ	YFB	Convection	Winter weather	Ceiling/ visibility
CMA	✓			✓			✓		
Environment Canada			✓	✓	✓	✓		✓	✓

Hong Kong Observatory	✓	✓		✓			✓		
Meteo-France		✓	✓				✓		
SAWS		✓					✓		
More to be added ….				`					

2.6 Funding

The AvRDP Airports and AvRDP Participants will participate in the AvRDP by their own funding. WMO may provide funding to support the travelling expenses for ASSC meetings and to the LDC for attending the capacity building training workshops, which would be considered case-by-case.

3. Deliverables

Major deliverables from the AvRDP will include: written reports to be submitted to WMO, findings to be presented in international symposia/conferences, journal publications, and capacity building training workshops for transferring the nowcasting technologies to other WMO Members.

The following AvRDP products are expected to be produced (subject to modification by AvRDP Participants during implementation):

(i) Meteorological product

(a) Convection

For local thunderstorms, 0-6 h nowcast of time- and space-specific storm tracks, intensities are produced. Forecasts updated every 6 min or faster depending on the update frequency of the radar and/or satellite. Spatial resolution varies from the remote sensor's data resolution (radar <0.5km, satellite 0.5-4km) closer to the airport to NWP model resolution of 10 km or so farther away from the airport.

(b) Winter weather

Low temperature, wind speed, direction, gust, precipitation amount, type and intensity nowcast for the next 0-6 h. Forecasts updated every 10 min or faster depending on the availability of surface observations and on the update frequency of radar and/or satellite. Some elements, such as precipitation type which may only be forecastable by NWP, may be subject to updates only several times daily.

(c) Visibility and ceiling

Ceiling and visibility deterministic or probabilistic forecast within TCA and over aerodrome are produced. Spatial resolution would depend on model resolution (e.g. horizontal 2.5 km, vertical 100-1000m or better). Time resolution could be hourly or shorter while the update frequency would depend on the model update frequency or surface observation measurement frequency.

(d) Uncertainty/reliability parameters

Use of model ensemble, time-lagged ensemble, statistical method or other techniques to estimate the uncertainty/confidence of the nowcast produced in (i)(a) to (i)(c) above.

(ii) ATM product

In order to demonstrate the value of MSTA products in aviation, nowcasting products will be translated into ATM impact for evaluation and validation. ATM impact products may vary depending on specific users such as ATM, airlines and ground operators. The impact parameters may include capacity estimates for runway, airport, arrival/departure fixes, and airspace sectors, expected flight delay time, fuel consumption, ramp closures, etc. The specific translation will require some form of collaborative studies, e.g. pilot avoidance study under significant convective weather (ICAO/WMO 2014c), between local MET and ATM researchers. ATM representatives need to be involved in this part of the AvRDP.

(iii) Verification and validation product

The verification matrix for aviation applications will likely be different from the conventional MET weather forecast verification matrix such as Probability of Detection (POD), False Alarm Rate/Ratio (FAR), Critical Success Index (CSI), Brier Score, Reliability, etc. In particular, verification indices emphasizing high impact (or rare) events would be required. Apart from the above, novel verification parameters which have more direct relevance to ATM impact may need to be developed in the AvRDP. Examples of aviation-relevant metrics may include capacity, delay or holding time, and cost estimates. The assessment of aviation-relevant impact parameters by necessity includes other information, such as operational status, traffic demand, runway configuration, etc. ATM validation may also include simulation experiments to explore sensitivities of traffic impacts to various nowcasting products.

Meanwhile, as the predictability of different weather systems inherently imposes some limits to the accuracy of the MET capability, it is therefore expected that the performance of the nowcast products may maintain some reliable skill level by varying the spatial and temporal resolution in different phases of a flight, namely, coarser resolution and less frequent update far from the airport while finer resolution and more frequent update closer to the airport. In other words, one should not expect that the nowcast products could maintain the same skill of performance at the same resolution all the way along the whole flight path. A varying resolution MET product along the flight path may be more realistic.

The assessment will utilize appropriate metrics for deterministic and probabilistic products.

More details about the verification and validation methodologies will be developed by a verification team to be formed under ASSC.

4. Organization

Four groups are to be established to guide and support the implementation of AvRDP（Fig.5）:

- AvRDP Science Steering Committee (ASSC):

  Responsible for steering the science and technical matters related to the AvRDP. The ASSC will include experts in nowcasting, mesoscale modelling, verification, and representatives from the AvRDP Airports, Participants, ATM, CAS/WWRP, CAeM and possibly CBS. Subgroups may also be formed within the ASSC for overseeing the various components of the AvRDP, e.g. verification team, if necessary. ASSC is responsible for reporting to CAS/WWRP and CAeM the progress of the AvRDP.

- AvRDP Airport Local Support Group:

  Each AvRDP Airport should form a local support group who is responsible for collecting the local observation data and ATM impact data during the IOPs and assisting the AvRDP Participants to configure their nowcasting system for running research at the Airport. The AvRDP Airport would also provide assistance to the evaluation team for evaluating the performance of the nowcasting products.

- AvRDP Participant:

  Responsible for configuring and implementing its nowcasting system at the AvRDP Airport(s) for conducting research and use the Airport's data collected during the IOPs to demonstrate the capability of its nowcasting systems. Each AvRDP Participant will have one person responsible for overall coordination and to act as a focus for interaction with the AvRDP Airport as well ASSC.

- AvRDP Website including Data Manager:

  A website will be established to facilitate dissemination of airport observation data, nowcast outputs, evaluation results, as well as information on the project documents, references, meetings, etc. A Data Manager will be responsible for overseeing the archiving of all the data. Guidance regarding data formats and metadata describing the formats and contents will be developed by the Data Manager.

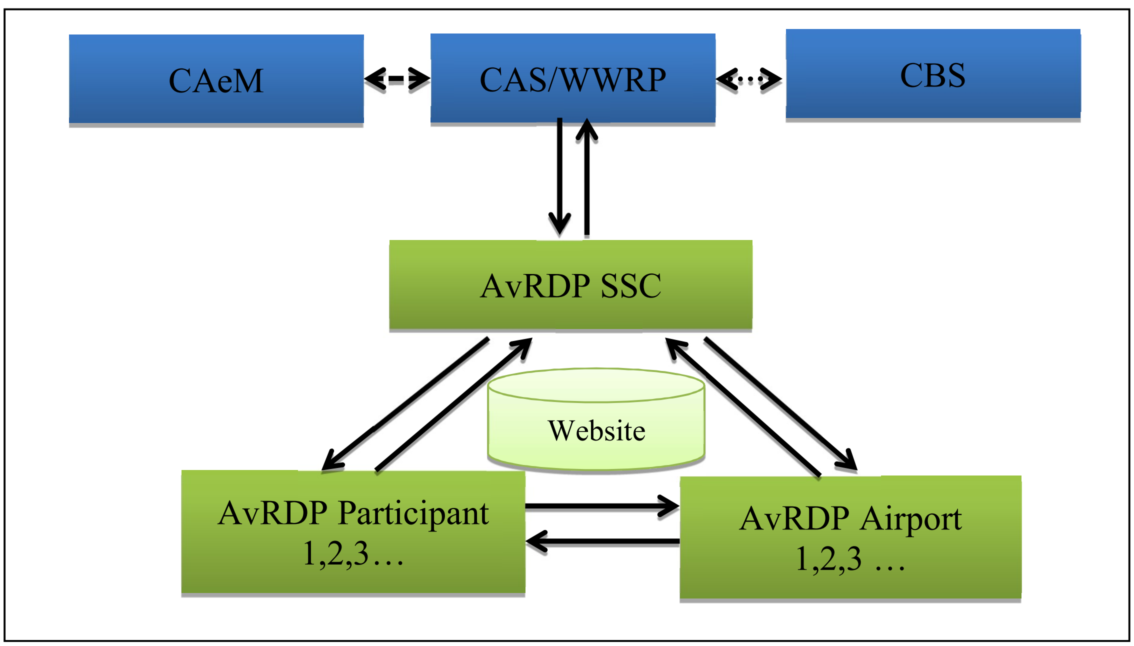


Fig.5 Organization of AvRDP

The composition of the ASSC is as follows:

Co-Chairs: *TBD*
Members: *TBD*.

The responsibility of the ASSC will be:

- Formulate strategies for the implementation of the AvRDP including:
  - (a) Determine the scope and schedule of AvRDP
  - (b) Provide guidance on translating MET information into ATM impact
  - (c) Provide guidance on the verification schemes
  - (d) Provide guideline on capacity building
  - (e) Keep in view of the development of other major aviation initiatives worldwide such as SESAR and NextGen and provide guidance on the need of collaboration with the initiatives
- Monitor progress of AvRDP implementation including review of the implementation plans of the AvRDP Airports and AvRDP Participants
- Oversee Training Programme
- Prepare reports and organize meetings

The interaction between the AvRDP and end users such as ATM and airline is a crucial part of the AvRDP. It is expected these issues will be resolved after the Kick-off meeting cum the Science Meeting.

5. Implementation

The AvRDP will involve a 2-year programme for Phase I (mid 2015- mid 2017) and another 2-year programme for Phase II (mid 2016 – mid 2018). Phase I will focus on the MET technologies and the associated MET verification, while Phase II will focus on the MET-ATM impact translation and Validation. The tentative time schedule is as follows:

Nov 2014	Endorsement of the AvRDP proposal
Nov 2014 – Feb 2015	Formation of AvRDP SSC and identification of AvRDP Participants
Jun 2015	**Kick-off Meeting cum Science Meeting**
May 2015 – July 2017	**Phase I – MET capacity research** (AvRDP Airports or Participants who need longer preparation time may choose to enter Phase I in late 2015 or after)
May 2015 - Oct 2015	1st IOP for convective weather (over Airports in Northern Hemisphere)
Nov 2015 – Mar 2016	1st IOP for winter weather, visibility and ceiling (over Airports in Northern Hemisphere)
Dec 2015 – Mar 2016	2nd IOP for convective weather (Southern Hemisphere)
May 2016 - Jul 2016	3rd IOP for convective weather (Northern Hemisphere)
Nov 2016 – Mar 2017	2nd IOP for winter weather, visibility and ceiling (Northern Hemisphere)
May 2015 – July 2017	Nowcasting research including MET verification on convective weather
Nov 2015 – July 2017	Nowcasting research including MET verification on winter weather, visibility and ceiling
20 – 22 Jul 2016	AvRDP Training Workshop on aviation nowcasting and verification
22 – 23 Jul 2016	2nd AvRDP SSC Meeting
25 – 29 Jul 2016	Preliminary Phase I results to be presented in WWRP Symposium on Nowcasting and Very-short-range Forecast
6-10 Nov 2017	WMO CAS/CAeM/CBS Aeronautical Meteorological Scientific Conference (AeroMetSci Conf)
Nov 2017+	Phase I To be expanded after the Scientific Conference
Jul 2016 – Jun 2019	**Phase II – MET-ATM impact translation and validation** To be expanded after the WMO AeroMetSci Conf

	(AvRDP Airports or Participants who started the IOP in late 2015 or later may choose to enter Phase II in late 2016)
Jul 2016 – Jun 2019	Research on MET-ATM impact translation
Jul 2017 – Jun 2019	Demonstration of MET-ATM impact
Early 2018 – mid 2018	Phase I of new airports (Sub-table)
Mid 2018 – mid 2019	Phase II of new airports (Sub-table)
Oct 2018	2nd AvRDP Training Workshop on MET-ATM integration
Mid 2019	Concluding Meeting

Sub-table

Early 2018 – mid 2018	Phase I of new airports
Jan – Feb 18	IGI Fog nowcast and forecast
Jun – Aug 18	SIN IOP and forecasting for convective weather
Sep – Oct 18	SIN performance evaluation and fine-tuning
Nov – Dec 18	SIN results and final report preparation for Phase II
Feb – May 18	LED IOP. Visibility and Ceiling nowcast
Apr – Jun 18	IGI thunsertorm and dust storm nowcast/forecast
Mid 2018 – mid 2019	Phase II of new airports (Sub-table)
Aug – Dec 18	LED Analysis and verification. Nowcasting data translation into ATM system
Jan – Mar 19	SIN operational trial on MET impact translation on ATFM and airside operation
Apr – May 19	SIN Review and data analytic
Jun 19	SIN Final Report
??	IGI Thunderstorm dust storm ATM Impact
??	IGI Fog ATM Impact
Oct 2018	2nd AvRDP Training Workshop on MET-ATM integration
Mid 2019	Concluding Meeting

6. Summary

A proposed AvRDP to provide enhanced nowcasting support for the MSTA as part of TBO has been described. The primary emphasis of the proposal is to demonstrate the MET capability of providing quality 0-6 h convective, winter weather and other weather nowcast for the Terminal Control Area. Deterministic and/or probabilistic nowcast will be generated and their impact on ATM and/or airline users will be assessed. The AvRDP represents a unique opportunity to demonstrate the utility of modern nowcast systems in high impact weather situations. Several IOPs will be conducted at different airports representing varied climatological regimes and associated range of weather impact to aviation. The AvRDP nowcasting products will be subject to objective evaluation/verification and their benefits to end users.

Relevance and Importance for the WMO Mission

The AvRDP will promote nowcasting science and services as part of the requirements for a weather programme of CAeM and CAS/WWRP. The AvRDP provides a vehicle for the demonstration of state-of-the-art nowcasting systems to the WMO Members and advance the science and technology of nowcasting for aviation. Training workshops and training materials on nowcast science and systems including verification and validation will be developed and available to WMO Members for capacity building in order to meet the ASBU requirements. The AvRDP will also demonstrate various options and innovative ideas in building advanced nowcasting systems in MET offices/MWOs. The above attributes clearly meet the requirements for a WWRP RDP.

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Appendix A
Current and Emerging MET Capability
(provided separately)

Appendix B
Foreseen MET Capability
(provided separately)

Appendix C

Table C1
Availability of information for participating in the AvRDP, including Airport Observations, Nowcasting facility, modelling facility and ATM data

Airport	Observations								Nowcasting system and model			ATM data				
	Weather Radar (conventional or Doppler)	Geostationary Satellite	Wind profiler	LIDAR	Anemometer	Visibility sensor	AMDAR/ACARS data	Other observations	Nowcasting system	Micro/mesoscale NWP	Regional model	PIREP	Aircraft data	ATM capacity data	Air traffic data	Miscellaneous (e.g. ADS-B)
CDG	✓	✓			✓	✓	✓?	✓	✓	✓	✓	?	?	?	?	
HKG	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
SHA	✓	✓	✓		✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	
JNB	✓	✓				✓					✓	✓				
YYZ	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓				
YFB	✓		✓	✓	✓	✓		✓	✓	✓	✓	?				
More …																

? = to be confirmed

CDG Observational Network and nowcasting/modelling facilities

1. Doppler Weather Radar

Météo-France operates several Doppler weather radars over the French territory, some of them being dual-polarization C-band radars. Near Paris-CDG airport, there is one of these C-band Doppler radar, located in Trappes (48° 46' 28.454" N, 02° 00' 29.914" E). The horizontal resolution is 1km and the update frequency is 5 minutes.

2. Satellite Data

The available VIS and IR and WV data are updated every 15 minutes from the Meteosat Second Generation (MSG) geostationary satellite. Rapid-scan mode imagery over Europe is also available, updated every 5 minutes (with some technical constraints).

3. Lightning Location Data

Data for lightning location coming from the Meteo-France's partner for lightning detection and location, Meteorage, will be provided to the AvRDP participants over a large area around Paris-CDG airport.

4. Surface Observation Data

The following surface observations will be provided to the AvRDP participants for Paris-CDG airport:

a. 12 wind sensors (3 sensors one each runway)
b. 12 Runway visual range (RVR) sensors data (3 sensors on each runway)
c. other conventional observation data, such as temperature, dew point, pressure, etc.

Observations from surrounding airports and meteorological stations could also be provided to the AvRDP Participants, such as data for Paris-Orly airport.

In France, METAR information is provided to the aviation community every 30 minutes. This set of data could also be made available to AvRDP Participants.

5. Other observations

Meteo-France operates a Sonic Detection And Ranging (SODAR) equipment at Paris-CDG for research purpose. Wind data in the very low altitudes could be made available from this equipment, as vertical wind profiles.

6. EUMETSAT Rapid Developing Thunderstorms product

Météo-France has been developing the EUMETSAT SAFNWC algorithm for the detection and monitoring of rapid developing convective cells, based on satellite imagery. This system is operated by the French Centre for Satellite Meteorology, using MSG imagery and also other satellites data more recently. The product RDT (Rapid Developing Thunderstorm) could be made available to the AvRDP participants.

7. AMDAR

Automatic MET data down linked from aircraft are available but Meteo-France has to pay the airlines for this data. A set of AMDAR data would be made available to the AvRDP participants within the TMA over Paris-CDG airport.

8. Numerical Weather Prediction

Météo-France operates several NWP models, with different horizontal resolution from the local scale up to the regional scale. The model which geographical coverage is the French continental territory is a 2.4km resolution model. Météo-France is in the process of upgrading this resolution to ~1km in 2015. Data from this HR model could be provided to the participants. Our regional model has a 0.1° resolution and data from this model could also be provided to the AvRDP participants. Finally Météo-France is on the process of operating a VHR model with a 500m resolution with the purpose of enhancing meteorological nowcasting and forecasting service on airports.

9. Human expertise-based nowcasting and forecasting meteorological service at CDG airport

Météo-France provides the Collaborative Decision making process community (ATM/ATC, airport management, airlines) with a high at-a-glance MET nowcasting and forecasting service where the final user-tailored product is the cdm@cdg website provided the users with MET products refreshed at a very high rate (less than 15min), with a fine temporal resolution. Most of the products available on the website are user-tailored and have been defined in close collaboration with the airport operators. Some of these products and/or data used to issue some of them could be made available to the AvRDP participants.

HKG Observational Network and nowcasting/modelling facilities

1. Doppler Weather Radar

Within the Hong Kong area, there are one S-band Doppler weather radars, one dual-pol S-band Doppler weather radar and a C-band Terminal Doppler Weather Radar near HKG (Hong Kong International Airport). There is also a X-band dual-pol Doppler weather radar operating near HKG. The update frequencies of the 4 radars are from 1 minute to 6 minute.

2. LIDAR

There are two infrared Doppler LIDAR operating at the HKG. The update frequencies of the two LIDARs are approximately 2 minute.

3. Satellite Data

The available VIS and IR MTSAT data are updated every 30 minute. Chinese FENGYUN-2D with an update interval of 15 minutes for targeted area is available. Korea Geostationary Meteorological Satellite COMS1 with update frequency of 15 minutes. The next generation Japanese Geostationary Meteorological satellite Himarari with update frequency of 10 minute will be available in mid/late 2015.

4. Lightning Location Data

A lightning locating systems with can provide CG and CC lightning location data within 500km radius from HKG.

5. Radiosonde Data and Surface Observation Data

During the IOP period, the radiosonde observation in Hong Kong, about 27km to the east of HKG, could be enhanced by the addition of 0600 and 1800 GMT soundings in addition to the current 000 and 1200 GMT soundings. Soundings from the nearby radiosonde stations over the southern part of China may also be available.

There are over 60 surface weather stations in Hong Kong area (including manned and automatic). Another 100 more AWS over Guangdong Province, the southern part of China adjacent to Hong Kong may also be available.

6. GPS Data

The 20+ ground GPS stations over Hong Kong can provide the information on total vapour amount and will be made available to AvRDP Participants. Some more ground GPS stations over and Guangdong Province may also be available.

7. Profilers and Lightning Locating Systems

Three wind profilers (one 3km and two 10km altitude height) updated every 10 minute will be available.

8. Ground-based instrument over HKG

There are 6 anemometer, 6 RVR and 6Forward Scatterers along the 2 runways of HKG. There are also a number of weather Buoys over the ocean next to the airport and a number of anemometer stations operating to the peaks over the Lantau Island next to the airport. Data from a MET Enclosure which hosts pressure, temperature, dew point sensors and rainguages will also be available. An EFM measuring the electrification of nearby thunderstorm is also available.

9. AMDAR

Automatic MET data downlinked from aircraft will be available.

10. Other Aircraft and ATM data

PIREP data are available.

By the mid of 2015, ADS-B data on the location of aircraft within the HKFIR will be available.

Real-time air traffic data over HKG will be available.

Real-time airport capacity notification will be available

All the above observational data will be sent to the AvRDP Website and each participating team can access the data from the web server.

11. **Nowcasting systems**

SWIRLS (Short-range Warning of Intense Rainstorms in Localized Systems) – a radar-based rainstorm nowcasting system provides quantitative precipitation estimate (QPE), quantitative precipitation forecast (QPF) up to next 9 hours, and nowcast of severe weather on lightning intensity, convective gust and hail over Hong Kong and nearby areas. The products are updated every 6 minutes.

A blending system named RAPIDS (Rainstorm Analysis and Prediction Integrated Data-processing System) combines QPFs from SWIRLS and the Non-Hydrostatic Model (NHM) to generate gridded rainfall forecast at a horizontal resolution of 2 km for the next 6 hours.

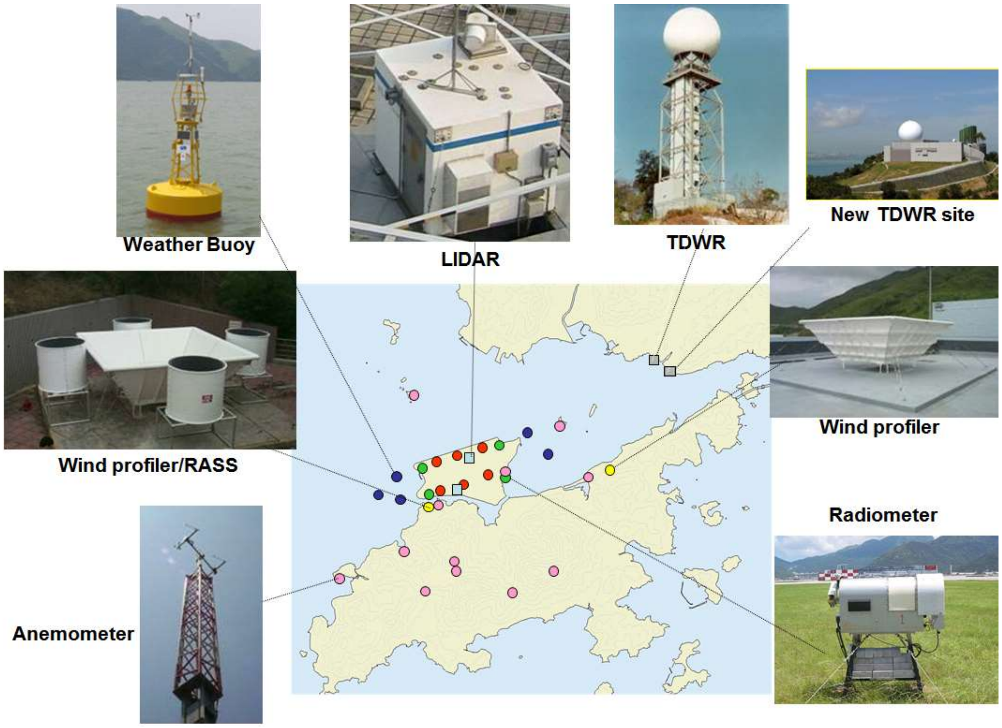
ATNS (Airport Thunderstorm Nowcasting System) – a SWIRLS-based convection nowcasting system for predicting the movement of convective activity within the terminal control area of HKG including aerodrome, arrival and departure rotes and way points within the air space, up to one hour ahead at 6-minute or shorter interval. The convection nowcast was translated into aviation impact represented by various level of significant (Green, Amber and Red) to represent various degree of air traffic impact (e.g. low, medium and high) based on aircraft avoidance study. ATNS products are updated every 6 minutes.

ATLAS (Airport Thunderstorm and Lightning Alerting System) – a lightning nowcasting alerting system is operated at the HKG to forecast and alert cloud-to-ground lightning stroke over the aerodrome. It makes use of lightning location information and SWIRLS echo tracking technology to predict and issue warning over HKG. ATLAS nowcast products are updated every 1 minute.

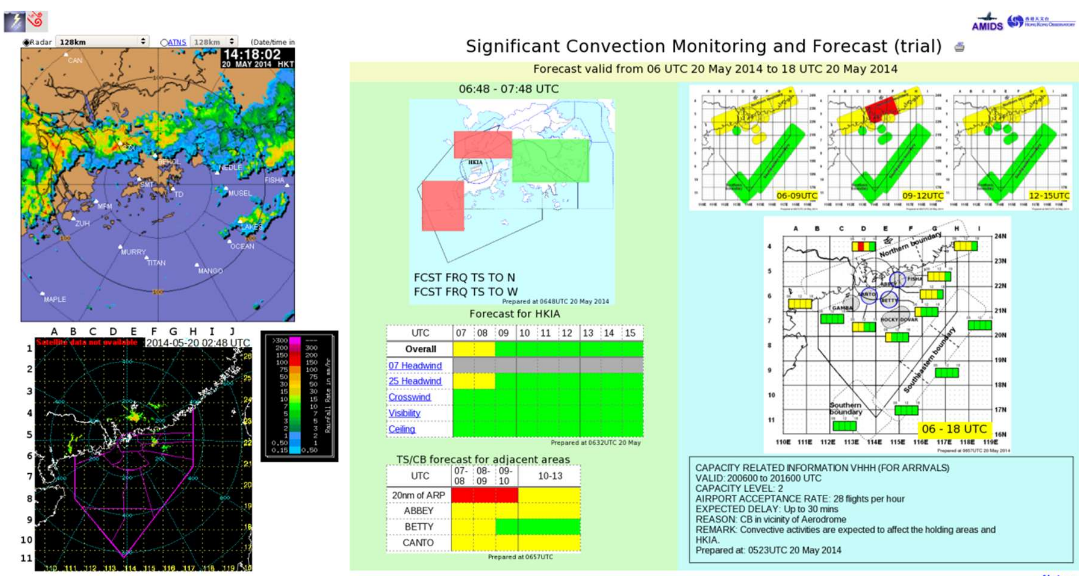
12. **Mesoscale NWP model and data assimilation system**

The Non-Hydrostatic Model (NHM) system is operated with horizontal resolutions at 10 km (Meso-NHM) and 2 km (RAPIDS-NHM) initialized by respective 3DVAR analysis. Meso-NHM is run every 3 hour providing 72 hours of forecast while RAPIDS-NHM is operated every hour giving 15 hours of prediction. Model forecast data can be made available in netCDF or GRIB format.

AVM – a sub-km mesoscale model down to 200 and 400m resolution is updated every one hour to predict windshear, temperature, and precipitation respectively over the HKG and its vicinity airspace. AVM is initialized by NHM to provide forecast up to 7 hours ahead. The model can also generate rapid output of 1 minute for aviation applications.



Met equipment over the HKG

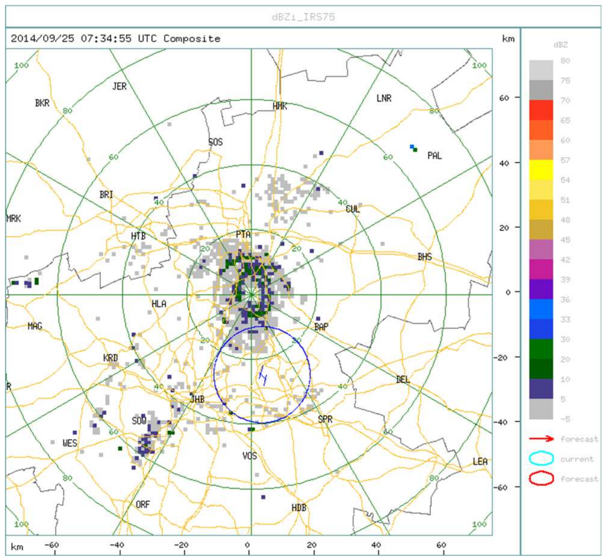


Significant Convection Monitoring and Forecast Suite (including ATNS, RAPID and Global Model)

JNB Observational Network and nowcasting/modelling facilities

1. Doppler Weather Radar

Irene S—band (10.5cm wavelength) radar located at: 25.911816S, 28.210766E, operates with a maximum range of 200km (for the volume scan) with a beam width of 0.93°. Twelve elevations are used, the lowest is 0.5° and the highest is 30°. It scans from the top down so that the lowest parts of the storm are the most recent data.



Irene radar image, with OR Thambo International Airport and its runways indicated by the small blue circle south of Irene.

2. Satellite Data

The available VIS and IR and WV data are updated every 15 minutes from the Meteosat Second Generation (MSG) geostationary satellite.

3. Lightning Location Data

The South African Weather Service operates a lightning detection network consisting of 24 Vaisala ground based sensors distributed across the country. The network consists of 19 - LS7000 and 5 - LS7001 sensors. These sensors are designed to detect cloud-to-ground lightning with a 90% detection efficiency and 0.5km location accuracy over most parts of South Africa.

Lightning Detection Network in SA

4. Radiosonde Data and Surface Observation Data
An upper air ascent is done twice daily at the Irene Weather Office (35km from OR Thambo).
O.R. Tambo - 1 AWOS system with:
a. Four Automatic Weather Stations (AWS) each with wind, temperature, humidity, ceilometer and visibility sensors
b. 6 Runway visual range (RVR) sensors
c. 1 solar radiation sensor
d. 1 present weather sensor
e. 1 rain gauge
f. 1 pressure sensor
g. 1 lightning sensor

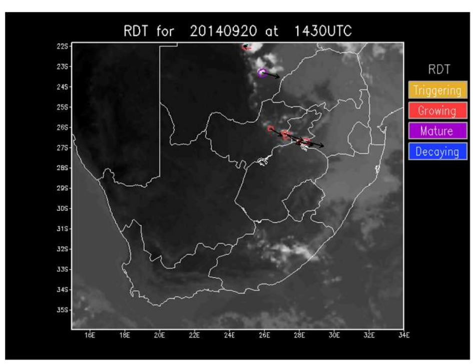
Nearby stations with AWS and/or surface observations:
Grand Central Airport (FAGC)
Rand Airport (FAGM)
Springs AWS (FASI)
Johannesburg Botanical Garden (AWS)
Irene W.O – RADAR (FAIR)
Lanseria Airport (FALA)
Waterkloof Airport (FAWK)

5. AMDAR
AMDAR data is available, but the SA Weather Service has to pay the airlines for the data.

6. Other Aircraft and ATM data
PIREP data are available – very little is available in SA.
Real-time air traffic data – not readily available
Real-time airport capacity notification - Central Airspace Management Unit (CAMU) has a way of communicating with all operators at the airport.
SAWS just have to disseminate information to a single recipient (at CAMU) from where it could be re-distributed.

7. Numerical Weather Prediction A local version of the UKMO Unified Model is run once a day at SAWS. This has a 12km resolution. We are in the process of upgrading to a new High Performance Computer and then the UM will be run twice daily at 4km for the southern African domain and 1.5 km over South Africa.

8. EUMETSAT Nowcasting SAF
The software developed by the Nowcasting SAF has recently been implemented at SAWS. The Rapidly Developing Thunderstorms product is now operational to identify and track more intense convective systems.



Rapidly Developing Thunderstorms product identifying three growing (red) storms over southern Gauteng province which produced hail on 20 Sep 2014 at 1430 UTC

SHA Observational Network and nowcasting/modelling facilities

1. Doppler Weather Radar
C-band dual polarization (5cm wavelength) radar located at: 31°12'N, 121°19'E, operates with a maximum range of 300km , with a beam width of 1.0°. The elevations range from -3.0° to 109°.

2. Satellite Data
The available VIS and IR and WV data are updated every 30 minutes from the Chinese FY-2E geostationary satellite.

3. Lightning Location Data
SHA gets lightning location data through the LTS2005 system from the Bureau of Shanghai City, which consists of several Vaisala ground based sensors installed in the Yangtze River delta region, including Chongming, Nanhui, Qidong, Wuxi, and other stations. The system covers an area within 200km radius from SHA.

4. Radiosonde Data and Surface Observation Data
SHA can get radiosonde data routinely from the Bureau of Shanghai City.

In Shanghai, there are 2 international airports: Hongqiao Airport (SHA) and Pudong Airport(PVG).
SHA - 2 AWOS system with:
a. 5 Automatic Weather Stations (AWS) each with wind, temperature, humidity, pressure, rain gauge
b. 6 RVR sensors
c. 1 present weather sensor
d. 4 ceilometers

PVG - 3 AWOS system with(the 4th AWOS is in construction):
a. 8 Automatic Weather Stations (AWS) each with wind, temperature, humidity, pressure and rain gauge
b. 9 RVR sensors
c. 4 present weather sensors
d. 6 ceilometers

5. AMDAR
AMDAR data is available.

6. Other Aircraft and ATM data
PIREP data are available – but in small number.
Real-time air traffic data – will be available
Real-time airport capacity notification – will be available.

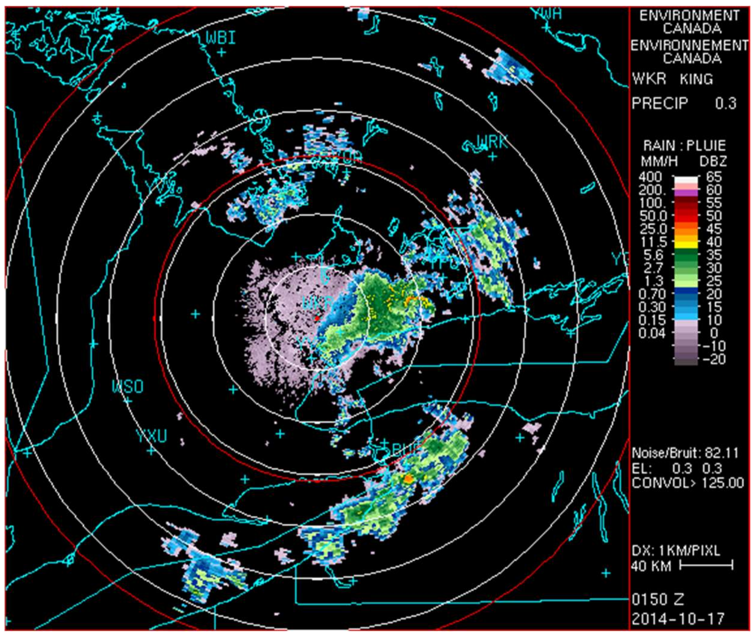
7. Numerical Weather Prediction
- **a. AMEFS:** A mesoscale short-range ensemble forecasting system over East China, with 3 domains which 36/12/4km resolution. AMEFS runs twice daily.
- **b. CANFS:** A mesoscale WRF system which runs 4 times daily with 3 domains which 36/12/4km resolution.

8. Shanghai terminal air control area meteorological service platform
The web-based system can tentatively predict the impacts of bad weather on the terminal ATC operating efficiency with the function of TAF decoding, weather radar mosaic extrapolation(in 1 hour, update every 6 minutes).

YYZ Observational Network and nowcasting/modelling facilities

1. Doppler Weather Radar

King Radar (WKR; 43.96389N, 79.57389W) is a dual-polarized C-band (5.33 cm) radar located approximately 30 km NE of YYZ. It has a 0.62° beamwidth. The conventional volume scan (18 elevations between 0.0° and 18.4° in winter; every 10 minutes) has a maximum range of 250 km. Three Doppler PPIs (0.0°, 1.5° and 3.5° in winter) are collected every 10 minutes with a maximum range of 112.5 km. Additionally Doppler scans are collected every 5 minutes for the lowest PPI level. Below is a sample hybrid precipitation product utilizing the radar's Doppler (inner 125 km) and conventional dataset (outer 125 km). Also obtained are dual polarimetric data and resultant prototype particle type classification output.

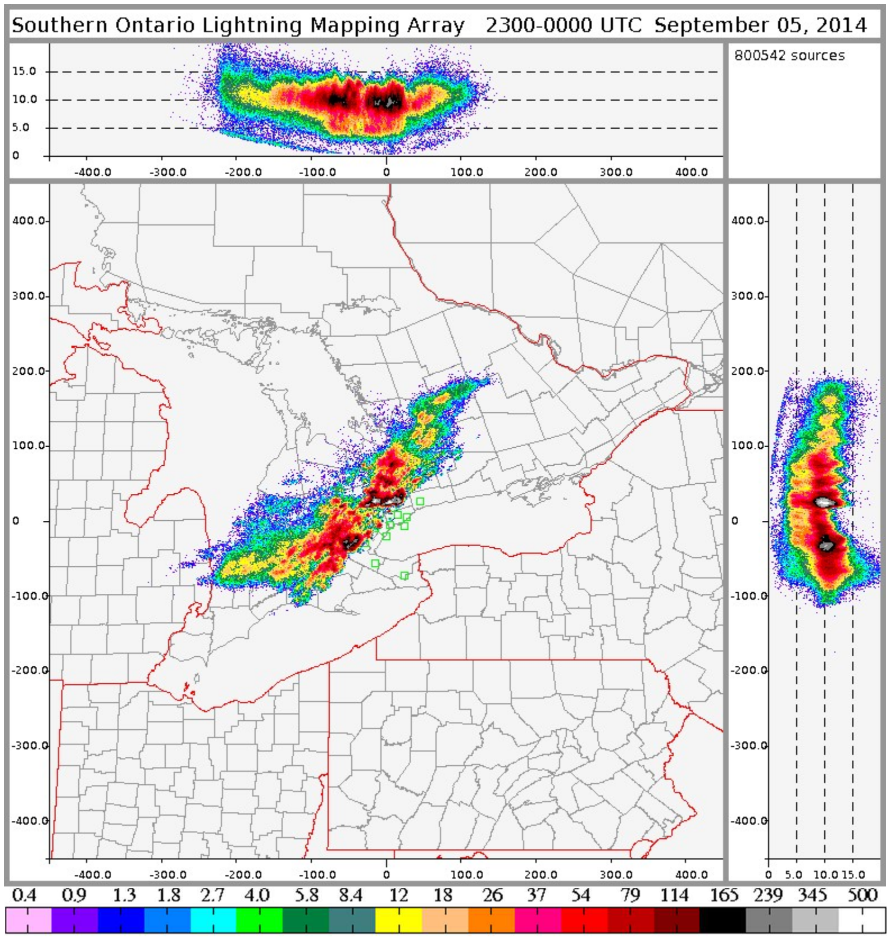


2. Satellite Data

GOES-13 East Imager data are available roughly every 15 minutes. GOES rapid scan imagery (every 5 minutes or better) could be made available with negotiation with NOAA. Additionally satellite products could be received as part of the GOES-R Readiness Plan being operated by NOAA and NASA.

3. Lightning Data

Cloud-to-ground lightning data are available through the existing Canadian Lightning Detection Network (CLDN). CLDN may also provide cloud-to-cloud information. Additionally a 3D Total Lightning Mapping Array (LMA) has been installed with 14 ground stations located around southern Ontario including YYZ. The LMA was deployed in 2014 and it will be used to evaluate the use of total lightning as a predictor of severe thunderstorms and to learn more about lightning characteristics in southern Ontario. Below is a sample LMA product for lightning data collected during a one hour period on September 05 2014.



4. Wind Profiler

A Vaisala LAP 3000 Wind Profiler is currently located approximately 60 km NW of YYZ. This pulse Doppler radar operates in clean air and reports data from the atmosphere up to 3 kilometres above ground level.

5. SODAR and LIDAR

A Doppler SODAR is currently located approximately 60 km NW of YYZ and its relocation is possible. This Doppler instrument provides vertically profiling wind and turbulence information to 1 km or more in favourable conditions. A scanning Doppler LIDAR is planned and may be available for this project.

6. Vertically Pointing X-Band Radar and Micro Rain Radar

Presently a 9.65 GHz vertically pointing X-band radar is located at YYZ. It has a 1.8° beamwidth and 45 m bin resolution. Data are usable up to approximately 10 km. Reflectivity and fall velocities are utilized to generate particle type products using an algorithm from McGill University. Additionally EC owns several METEC Micro Rain Radars. One may be available for this project. Either and/or both radars can be used to collect particle type (e.g. rain, snow, freezing rain, freezing drizzle, etc.) and bright-band information.

7. Other Surface Observations

The meteorological compound at YYZ is equipped with the following surface sensors. Most data are available in real-time every 1 minute.

Visibility and Present Weather Sensor (Vaisala FD12P)
Present Weather sensor and derived Precip Type (Parsivel)
Ceilometers (Vaisala CT25K and Jenoptik CH)
Relative Humidity and Temperature sensors
Precipitation Occurrence Sensor System (POSS)
Rosemont Icing Detector
Belfort Precipitation gauge
Geonor Precipitation gauge
Ultra sonic wind speed sensor (Vaisala WS425)
Ultra sonic snow depth sensor (Campbell SR50)
Web camera images

8. PIREPS

PIREP data (North America) are available at EC.

9. Other Aircraft and ATM data

AMDAR and ACARS data are available however coverage may be very limited over YYZ. The Canadian Air Navigation System is managed by NAV CANADA and ATM data is not available to EC at this time.

10. Numerical Weather Prediction

The Canadian GEM (Global Environmental Multiscale) Regional Deterministic Prediction System (RDPS) is a 10 km resolution NWP model covering most of North America. A high time resolution point-based output version of the RDPS is available with 80 vertical levels and sub-10 minute time step. Model point output is available for YYZ and a grid of points surrounding the airport. The GEM High Resolution Deterministic Prediction System (HRDPS) 2.5 km model also covers YYZ and similarly high time resolution output at the airport is available at 5 minute time step. The forecast length is 48 hours. Additional GEM HRDPS 250m and/or 1km resolution versions can be run in hind cast mode for case studies.

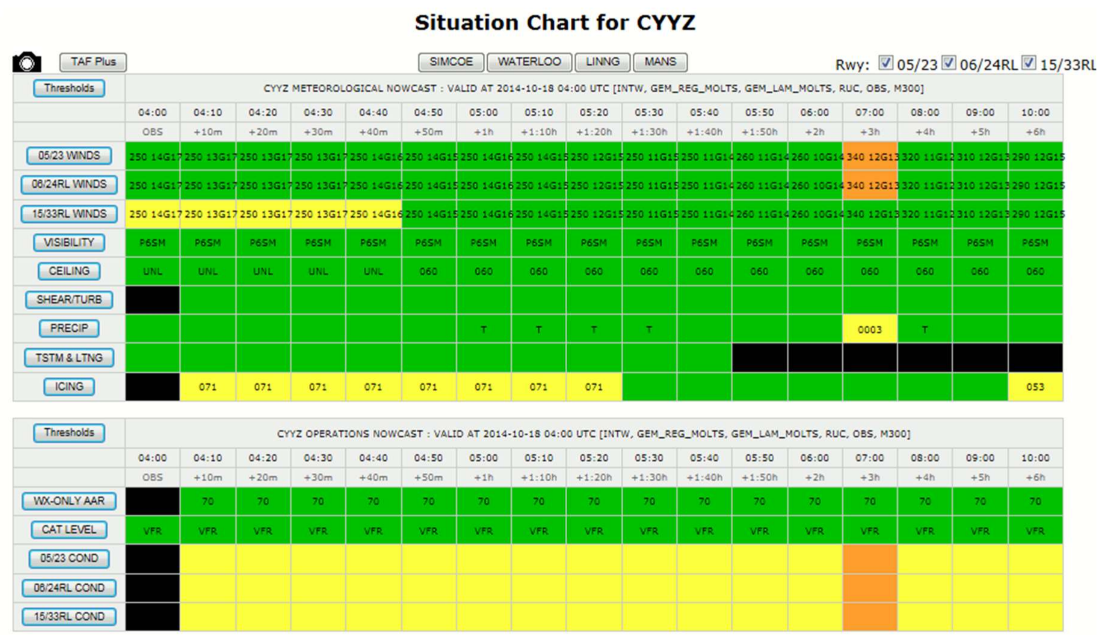
11. Nowcasting Systems

11.1 Integrated Weighted Nowcasting (INTW)

Integrated weighted nowcasts (INTW) are generated by blending observations and n-number of NWP model forecasts to form a single integrated nowcast out to 8 hours. At each site the system nowcasts for variables with direct matching observations and NWP output such as temperature, relative humidity, wind speed, wind direction, gust, visibility and ceiling. A dynamic weighting and bias correction algorithm is used. The system has been demonstrated with success as part of the WMO/WWRP projects the Science and Nowcasting of Olympic Weather for Vancouver 2010 (SNOW-V10) and Forecast and Research in the Olympic Sochi Testbed (FROST-2014). The system has also been operating at YYZ for the past 5 years as part of the Canadian Airport Nowcasting (CAN-Now) project and will be demonstrated during the Toronto 2015 Pan Am and Parapan Games this summer.

11.2 CAN-Now

A specific product developed for the CAN-Now project is called the Situation Chart (see diagram below). This chart depicts present weather and forecasts for crosswind for each airport runway, visibility, ceiling, shear/turbulence, precipitation, thunderstorms and lightning, icing aloft, weather-only arrival rate, CAT level, and runway condition. The product has been generated for YYZ for the past 5 years. The nowcasts include predictions for each 10 min in the first two hours and then hourly out to 6 hours. The forecasts on the Situation Chart change color when certain thresholds are crossed. The nowcasts rely mainly on those from the INTW system (see Section 11.1) and is augmented by forecasts for icing and lightning which in part make use of the RDPS NWP model (see Section 10).



11.3 Aviation Conditional Climatology (ACC)

This system utilizes airport-specific climatological data to forecast variables at an airport. Variables include cloud ceiling, visibility, thunderstorms, forms of precipitation, and significant wind. For this forecast system, site climatology is combined with time information (time of year, time of day), current observations and trends, and model-based predictions to produce deterministic and probabilistic forecasts of ceiling and visibility.

11.4 Canadian Radar Decision Support (CARDS) System

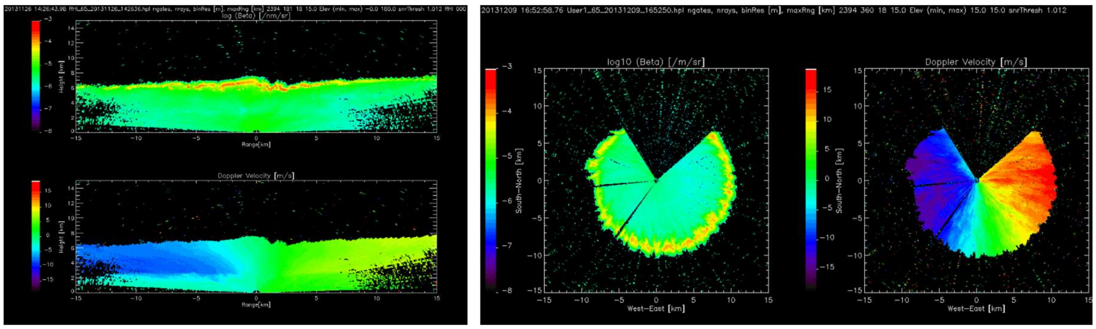
The CARDS Point Forecast nowcasting module is a radar-based algorithm that uses a cross-correlation technique to forecast precipitation at specified locations at 10 minute intervals for the next 3 hours.

YFB Observational Network and nowcasting/modelling facilities

1. Scanning Doppler Lidar

The scanning Doppler Lidar measures winds and aerosols. The system provides these data 360º around the site and up to 10 km. Instrument installation is planned for 2015-2016.

Example scanning LIDAR range-height plots (left) and PPI products (right) are shown below.



2. Scanning Doppler Ka-band Radar

The scanning Doppler Ka-band radar (METEK Doppler Cloud Radar MIRA36) is dual-polarized and detects winds, cloud and fog. Scan patterns (RHI, volume scans, PPIs, etc.) are programmable. Instrument installation is planned for 2015-2016.

3. Scanning Doppler X-band Radar

The scanning Doppler X-band radar (Selex Meteor 60DX) is dual-polarized and measures precipitation and winds. Instrument installation is planned for 2016-2017.

4. Profiling Microwave Radiometer

The passive profiling microwave radiometer (Radiometrics MP-3000A) provides vertical profiles of temperature, relative humidity, liquid water content and water vapour up to 10 km. Additionally the unit measures cloud base temperature and thus infers cloud base height. Instrument installation is planned for 2015-2016.

5. Ceilometer & Visibility Meter

Instrument (Vaisala CL31L and PWD52) installations are planned for 2015-2016.

6. Wind Profiler

A 442Hz wind profiler provides continuous, high resolution (100 m) wind profile data up to 8 km every 5 minutes. Instrument installation is planned for 2016-2017.

7. Scintillometers

This instrument measures heat fluxes which can be used in NWP validation. Instrument installation of two units is planned for 2015-2016.

8. Low Power Phased Array X-band Radar (LPAR)

Radar manufacturer Raytheon and the University of Massachusetts are proposing to deploy an LPAR at YFB as a demonstration of technology in the Arctic under the U.S. Defense Advanced Research Projects Agency (DARPA) program. This X-band radar is low maintenance, low infrastructure and low cost and can serve airport weather surveillance and hazard detection. Proposed installation is for 2016-2017.

9. Other Surface Observations

An existing meteorological observing station reports hourly and special observations of temperature, dewpoint temperature, pressure, relative humidity, wind speed, direction, gust, ceiling, visibility, sky cover and present weather.

Existing enhanced YFB surface observations collected by the Meteorological Service of Canada (MSC) include:

Temperature, dewpoint temperature, pressure, winds
Precipitation intensity, amount, type (Geonor, OTT Pluvio2, Vaisala PWD22, POSS, Campbell PWS100, Parsivel, HotPlate)
Visibility (Vaisala PWD22)
Icing (Rosemount icing detector)
Snow depth (Campbell SR50)
Particle Imaging Probe (PIP)

These data are collected sub-minutely and available within several days of collection.

10. Ozone/radiosonde launches

Periodic ozone/radiosonde launches are planned at YFB.

11. PIREPS

PIREP data (North America) are available at EC however coverage may be very limited over YFB.

12. Other Aircraft and ATM data

AMDAR and ACARS data are available however coverage may be very limited over YFB. The Canadian Air Navigation System is managed by NAV CANADA and ATM data is not available to EC at this time.

13. Numerical Weather Prediction

Same Canadian GEM model output as for YYZ are available for YFB.

14. Nowcasting Systems

14.1 Integrated Weighted Nowcasting (INTW)

As described in previous YYZ section.

14.2 Aviation Conditional Climatology (ACC)

As described in previous YYZ section.