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FINAL REPORT OF CDG AIRPORT

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Summary

The participation of CDG airport to the AvRDP consists of demonstrating the added value to the airport MET service of the innovative MET capability called CDM@CDG, supported by enhanced NWP capabilities especially for nowcasting, and benefits to the local ATM community, airlines and airport management. The involvement of the MET community from the start of the development of the Collaborative Decision Making process at the airport and a close and continuous collaboration of the two communities were two keys of success. Further work is needed for a continuous improvement of the forecast (e.g. runway state, visibility/fog) and towards the inclusion of probabilistic information, and more integration of the impact-translated MET information into ATM systems in line with the Global Air Navigation Plan ASBU requirements.

I. Introduction

(1) Airport information

Paris-CDG airport is located inland and mid-latitude in the Northern Hemisphere (49°N, 02°W), North-East from Paris. It has 4 runways suitable for heavy-body aircraft (2x 2700m, 4200m, and 4215m): 08L/26R, 08R/26L, 09L/27R, 09R/27L. Statistics of 2017 say 69.5 M passengers, 475,000 movements with 1,400 per day. 146 airlines operate at Paris-CDG. In nominal conditions, runway throughput is 73 arrivals and 76 departures. In World Airport Traffic Report published in 2018 by ACI World, Paris-CDG is ranked number ten for total passenger traffic.

ATC infrastructure includes one approach room, 3 control towers and 2 apron control centers. Paris-CDG being one of the three Paris airports, during special situations including those caused by adverse weather, approach and airport operations are managed in a coordinated way with other surrounding airports in the Paris control area.

(2) Impacting weather

Major meteorological phenomena impacting Paris-CDG operations are:

- Fog: low ceilings and visibility due to fog and stratus are primary causes of airline delays (~40%), terminal area disruption and GA accidents. During low ceiling and/or low visibility conditions, arrival capacity can drop down up to 39 aircrafts per hour. After one hour of LVP conditions, 27 aircrafts (among 66 in normal conditions) are in stack areas and the delay for the 27th one is around 42 minutes!
- Convection: causes landing or take-off delays, modifying approaches, is dangerous for ground personnel. All French airports are concerned, more delays if convection is around Paris. An example of a disruptive convective day is the 10th of August 2014, between 12h and 15hUTC. A severe TS occurred with gusts over 40kt. Impact on arrivals was a 12' stand-by in landing operations, and a 17' ground operations interruption for Air France. Operators also experienced delays in departures with no take-off during 11', and a 17' Air France ground operations interruption.
- Winter weather i.e. cold temperatures/ground and aircraft icing/snow/freezing precipitation etc.: these phenomena cause delays and flight cancellations at the airport. Even a light snow fall can cause terminal area disruption. During the famous 2-day non-stop snow event in Dec 2003, 25% flights were cancelled, delays were more than 2 hours per flight and around 5,000 passengers were stuck inside terminals and 5,000 were in hotels! A very disruptive event that could occur again, knowing that during winter 2017/2018 a total of 19 days with snow were registered (19cm cumulative snow layer thickness).

(3) ATM/Airline/Pilot/Aviation Community Needs

The meteorological phenomena affecting Paris-CDG airport as described in (2) above require *precise and satisfactory forecasting* to alleviate Air Traffic Control (ATC) services in their effort of avoiding airline delays, terminal area disruption and general aviation accidents. Thus, *good meteorological information accuracy and a high refresh rate* are crucial for Air Traffic Management (ATM) especially during fog and low visibility events, convective weather and wintry conditions.

Since 2003 airports in Europe have become bottlenecks. With growing airport delays but diminishing en-route delays, a congestion point was noticed. Moreover the Single European Sky regulatory package from the European Union came into force introducing requirements for the European air traffic management: *to triple the capacity (by 2025), to reduce ATM costs by 50% per flight, to increase the safety by a factor 10 and to reduce the environmental impact per flight by 10%.*

During the Dec 2003 snow event at Paris-CDG stakeholders used to work in silos, without any coordination and information sharing. Based on this evidence and after such a costly experience, main actors on that platform decided to launch the CDM@CDG program in order to deploy the Airport Collaborative Decision Making (A-CDM) concept with Eurocontrol rules and in line with the SES requirements, in order *to reduce delays, to improve departures and arrivals predictability, to reduce taxi-*

time, kerosene consumption and polluting emissions and to optimize airport capacities and resources usage. These targeted operational improvements could not be reached without optimizing operational collaboration between stakeholders, in particular without reinforcing sharing of information including meteorological information. Thus meteorology got a full role from the beginning of the CDM process implementation. In that context, the ATM, airlines and airport manager needs included:

- Enhanced meteorological information (in comparison to existing old-fashioned legacy products) with a finer temporal and spatial resolution, a higher accuracy and updated as often as the meteorological situation would require;
- More communication towards platform stakeholders for a better understanding of the situation; this could mean involving airport met experts (managers or forecasters) physically participating to CDM operational units such as a crisis cell;
- The development of tools to meet customer needs and expectations. At Paris-CDG a dedicated MET working group was set up for that purpose; and
- A good level of sharing of MET information for pro activity, between all stakeholders, aiming at a common situational awareness.

As a response to CDM users' needs, an innovative solution was set for Paris-CDG operations, allowing a common weather hazard awareness. It integrates the impact of weather on terminal area and platform operations. It is performed thanks to human expertise at a fine temporal resolution and a high refresh rate. Through this user-tailored system, the latest science in forecasting techniques, including probabilistic information is provided to operators and stakeholders.

(4) Study approach and timeline

For the Aviation Research and Development Project (AvRDP) purposes, Paris-CDG is a participating airport and the chosen study approach consists in analysing several meteorological situations having a known impact on airport operations during three observation periods: winter 2015-2016 and winter 2016-2017 as for AvRDP Phase 1, and winter 2018-2019 as for Phase 2 focussing on impacts on ATM.

II. Outcomes

(1) Phase I achievements (MET Capability)

The participation of Paris-CDG airport in AvRDP Phase I consists of analysing several meteorological situations in winter with impact on operations. Benefits of providing using enhanced NWP nowcast systems were identified:

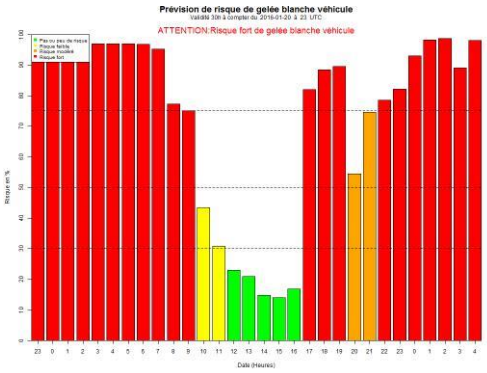
- Icing fog is one of the most threatening weather phenomenon for Paris-CDG operations and occurs quite regularly during the winter season. Météo-France nowcast model AROME-PI allows a better anticipation of the icing fog forming and of fog evolution in general. Thanks to a higher refresh rate than the regional models of Météo-France, the forecast fields are more accurate and better represent the microphysical processes.

- Industrial snow is becoming a frequent threat at Paris-CDG and has safety and economic consequences. It is still a complex phenomenon in terms of forecast given the difficulty of modelling it with limited aerosol observations. An industrial snow diagnostic is currently under development at Météo-France, and regional and nowcast models give extra information on runway temperatures and snowfall

- Ice is one of the most impacting phenomenon for Paris-CDG operations. Nowcast data such as temperature profiles and ice diagnostic from Météo-France's nowcast model and runway temperature diagnoses allow better anticipating such a threatening event.

- Other case studies enlighten the interest of using nowcast models to better forecast low visibilities and hence alleviate the ATM work load in case of Low Visbility conditions triggering LVP and ATC regulations.

Phase I studies reports illustrate the positive impact to the ATM operations of the extra information provided by state-of-the-art models such as Meteo-France's nowcasting model AROME-PI and ANTIGEL, the vehicle icing risk statistical model, for a high-traffic airport during bad weather situations and through the innovative CDM@CDG tool. (Figure 1, a case of on-ground airframe icing; Figure 2, a case with ice on ground, forecast with insufficient anticipation)



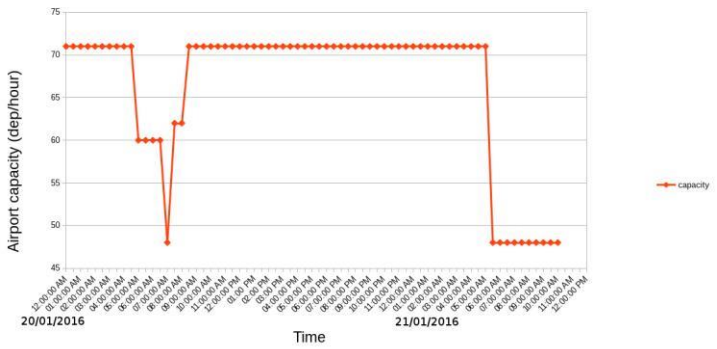


Figure 1: (top left) Weather predictions from the CDM@CDG tool updated on January, 21st 2016 at 03:02Z ; (top right) Display of output from the on-ground airframe icing model of Météo-France available on January, 20th at 23Z ; (bottom) Paris-CDG airport departure capacity from January, 20th 2016 at 0Z to January, 21st at 12Z

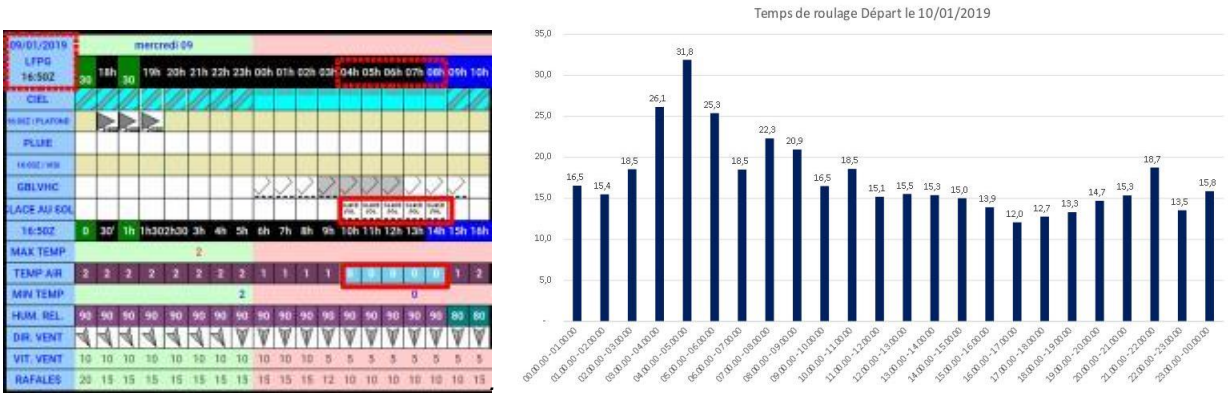


Figure 2: (left) Graphical forecast product called Aerogramme from CDM@CDG ; (right) Hourly rolling time at departure from Paris-CDG

(2) Phase II achievements (MET-ATM Integration)

The participation of Paris-CDG airport in AvRDP Phase II consists of analysing several meteorological situations in winter focussing on the impact on airport and ATM operations. Phase II studies report illustrates the benefit to the ATM operations of the meteorological information coming from Météo-France nowcast and mesoscale high resolution model through the CDM@CDG platform. A better management of flight arrivals and departures in case of on-ground icing conditions, LVP conditions and snowy runways is facilitated thanks to an improved assessment of such events' timing and severity.

The report also points out an area for future improvements, as an earlier anticipation of such events by forecasters could help ATM to take more efficient measures for flights arrival and departure management.

Both studies highlight that the translation of MET information in terms of impact on operations, for instance by applying user-defined thresholds on met parameters and deriving warning products and advisories, allows to make the information more fit-for-purpose and ready for integration into ATM/airlines/airport management systems. (Figure 3: user-defined thresholds for temperature and wind, and the usage in forecast graphical products to provide impact-translated information)

TEMPERATURES FROIDES	> 3°C	=< 3°C	=< 1°C	<= -7°C
TEMPERATURES CHAUDES	< 32°C	>= 32°C	>= 35°C	>= 40°C
VENT MAX FREQ/EXTR	< 25kt	>= 25kt	>= 40kt	>= 55kt
VENT TRAVERS MOYEN	< 25kt	>= 25kt	>= 30kt	>= 35kt
VENT TRAV FREQ/EXTR	< 25kt	>= 25kt	>= 38kt	>= 50kt

Vent de face supérieur à 5kt	Vitesse inférieure ou égale à 5kt, de face ou arrière	Vent arrière < 10kt	Vent Arrière < 15kt	Vent Arrière > 15kt

Composante « de droite »	Composante « de gauche »	Signification
		Composante transversale nulle (vent dans l'axe ou calme)
		Composantes vent moyen et rafales < 25kt
		Composantes vent moyen < 25kt avec rafales >= 25kt
		Composantes vent moyen < 25kt avec rafales >= 38kt
		Composantes vent moyen < 25kt avec rafales >= 50kt
		Composantes vent moyen et rafales >= 25kt
		Composantes vent moyen >= 25kt avec rafales >= 38kt
		Composantes vent moyen >= 25kt avec rafales >= 50kt
		Composantes vent moyen >= 30kt avec rafales >= 38kt
		Composantes vent moyen >= 30kt avec rafales >= 50kt
		Composantes vent moyen >= 35kt avec rafales >= 50kt

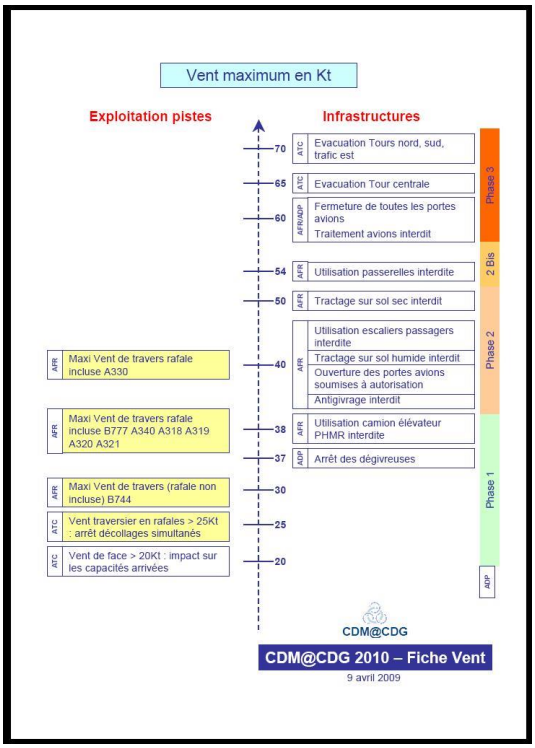


Figure 3: (bottom right) impact of strong winds on operations, thresholds on wind speed; (bottom left) usage of wind thresholds in graphical warning product; (top) usage of wind and temperature thresholds in graphical forecast and warning products

III. Summary

(1) Benefits to local ATM

Few years after the implementation of the CDM@CDG process benefits to local ATM and to airport and terminal area management were visible. Improvements on safety, punctuality, taxi time, crisis management, risk assessment, platform performance and capacity as well as more confidence in improved forecast were noticed. The following figures (2017) illustrate that outcome: thanks to the use of MET information within CDM@CDG, reduction of aircraft queueing (- 40%), less ATC delays and less taxi time (up to -20%). A positive environmental impact has also been registered: less fuel burn (6,600 tons), less emissions of CO2 and SO2.

More generally, all ATM actors have interest and benefit the CDM@CDG service including the MET information one:

- ✓ for Eurocontrol the European **Network Manager** : more up to date and accurate information leading to better network planning
- ✓ for the **airport operator** : improved use of stands/gates
- ✓ for the **ground handler** : more accurate arrival times and planning. Better planning and use of resources

- ✓ for the **aircraft operator** : improved awareness about the status and location of the aircraft, more accurate fleet predictions. Significant decrease in fuel costs - for the environment: less noise and lower CO2 and NOx emissions

- ✓ for the **air traffic controllers** : reduced workload due to a greater predictability of traffic

- ✓ for the **passenger** : reduced delays and probability of missed connections, better reliability on flights meaning improved customer satisfaction

(2) Contributions to ASBU

The implementation and running of the enhanced airport MET service and a CDM process with a MET 'dimension' such as the one at Paris-CDG airport contributes to the supporting concepts of and the implementation of ASBU Blocks 0 & 1 AMET modules:

See https://www4.icao.int/ganpportal/ASBU AMET thread and modules.

AMET-B0: Global, regional and local meteorological information to support flexible airspace management, improved situational awareness, collaborative decision-making and dynamically optimized flight trajectory planning

AMET-B1: Meteorological information supporting automated decision process or aids, involving meteorological information, meteorological information translation, ATM impact conversion and ATM decision support

Collaborative decision making is made possible or is facilitated by a good level of sharing of information between all stakeholders and a common meteorological situational awareness.

In particular, the description of AMET-B1/2 module for 'Meteorological forecast and warning information' refers the use of user defined thresholds: 'Human-readable meteorological advisory and warning products start to be derived from the meteorological information/data to better suit user needs and can be based on user defined thresholds. Meteorological information to be used to assess impact.'

The innovative MET service implemented at Paris-CDG airport under the CDM@CDG process fulfils that specific requirement and contributes well to the GANP/ASBU implementation.

(3) Gap identified

Studies carried out for Paris-CDG airport as one of the AvRDP participating airport highlighted the benefits to the local ATM, airlines and airport manager of an enhanced airport MET service for the provision of impact-translated meteorological information with high temporal and spatial resolution and high refresh rate. The 'impact-translated' character of that information derives from the use of user-defined thresholds. The overall service has been satisfactory for all actors on the platform, and benefits to all were demonstrated including in terms of costs and of environmental impact. The following gaps were identified though:

- In few meteorological situations with strong impact on the airport operations, the forecast was considered good as far as the phenomena and the timeline of occurrence were concerned. However feedback from some airports stakeholders

and results from AvRDP studies show that an earlier anticipation would have allowed airport managers to better organize equipment and human resourcing.
    - This gap in the forecast service could be fulfilled thanks to NWP technics enhancements, aiming at an earlier anticipation of the weather hazards (here, a snow event)
- Most of the meteorological information available at CDMCDG web site is for the airport itself i.e. the surface. As operations at airport (surface) and in the terminal area for approach, final approach and climbing (altitude) are closely linked, the CDM@CDG service would need to be supplemented with further observation and forecast information over the whole Paris area (control area), over the approach paths around Paris-CDG and the stack zones (e.g. convection risk over these stack areas).
    - This gap has been under consideration by the MET working group of the CDM program for few months, in particular involving the French ANSP/ATC and Météo-France representatives.
- Most of the meteorological information available at CDMCDG web site is deterministic data. The probabilistic information already provided is only qualitative (light/medium/high probability) and only in few cases, based on outputs from the Météo-France ensemble forecasting system. As so, this information does not or very poorly allow airport stakeholders to develop a full risk assessment process. However, there is a growing need for probabilistic meteorological information supported by a scientifically sounded training and education on the usage of this information.
    - It is expected that projects and studies under the SESAR 2020 program would consider that need and develop concept and technical solutions that after deployment, would allow fulfilling that gap.

IV. Recommendation

(1) Future Studies

In parallel to further developments that would be needed to improve the accuracy and timeliness of nowcast and forecast of high-impact weather phenomena, the MET community is expected to work jointly with the ATM community towards more integration of MET information into ATM decision-support or –making systems. That would imply the following:

i. In terms of meteorological information, there is a growing demand for the provision of runway state data (temperature, status, contaminants like snow, ice, etc.) in order to fulfil the newly introduced ICAO requirements for Global Reporting Format (runway surface condition assessment and reporting that come into effect in November 2020 as outlined in ICAO Circular 355, Assessment, Measurement and Reporting of Runway Surface).

ii. As more interoperability between systems is required by the newly introduced SWIM environment, and leading to more and more machine-to-machine or business-to-business (B2B) communication ways, it is of paramount importance that the meteorological information is well fit for the purpose of the management of airport operations and in the

terminal area, consequently is translated into impact. A basic example of this impact-translated information could be wind data at airport: the sole provision of total wind speed and direction forecast (possibly also gusts) is nowadays far insufficient, as operators need forecast data of crosswind or tailwind passing over operational thresholds, supplemented with probabilistic information to allow a better arrival/departure demand and airport capacity balancing predictability. The concept supporting ASBU Block 1 AMET modules introduces that translation need: "Meteorological information supporting automated decision process or aids, involving meteorological information, meteorological information translation, ATM impact conversion and ATM decision support". It is highly recommended that both ATM and MET communities collaborate closely for the definition of translation principles, at both global and national/local levels.

iii. For the same purpose as above, the impact-translated information needs to be integrated into ATM and airport decision-support systems. Further studies based on that concept have been launched within the SESAR2020 program. Rules for the usage of that translated MET information into decision aid systems should be established by the ATM community and feedback be given to the MET community for further enhancements of the MET information service.

(2) Plans

At Paris-CDG, plans for the enhancement of the CDM@CDG MET service in the next few years would include:

- An increased use of outputs from the Météo-France ensemble forecast system especially to support the requested provision of probabilistic information of convection to the ATC community covering the 0 to +6h forecast ranges;
- Extension of the enhanced service to the Paris area, surrounding Paris-CDG and Paris-Orly airports and encompassing the whole Paris air traffic control area;
- Research and development for runway state forecast: enhancements to the runway temperature and state prediction model including a systematic control/verification of the forecast runway surface temperature against quality-controlled observations from stations implemented at CDG on runway surface, a preliminary study for introduction of those observations in a data assimilation process, and a probabilistic approach of the temperature modelling
- The development and deployment of a portfolio of SWIM compliant services to request and retrieve airport MET information (observation and forecast); information already available through the CDM@CDG (MET) website would be accessible via (web) services allowing direct/automatic integration of MET data into ATM systems
- Other studies and projects would be conducted in the near future in the framework of SESAR 2020 program, involving Météo-France as a partner of the French ANSP or of any industrial, focusing especially on the concept for integration of impact-translated MET information into ATM/ATC systems.

V. References

- ICAO Global Air Navigation Plan 6th edition (under development, to be published late 2019), https://www4.icao.int/ganpportal/
- AvRDP Phase I and Phase II CDG airport reports (url?)
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Appendix (including the details of the following but not limited to)

Instruments employed
MET and ATM Data used
Algorithms
Nowcast and/or NWP models
ATM KPI (if any)
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