The WMO Aviation Research & Demonstration Project (AvRDP) at Paris-CDG airport.

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Introduction

The Aviation Research and Demonstration Project (AvRDP) is a joint effort between the World Weather Research Programme (WWRP) and the WMO Commission for aeronautical Meteorology (CaMe). It aims at conducting research in mesoscale modelling and nowcasting at six international airports located in Northern and Southern Hemispheres to support the development of the next generation aviation initiative, the Aviation System Block Upgrade (ASBU) under the new Global Aviation Navigation Plan (GANP) endorsed by the International Civil Aviation Organization (ICAO). Collaboration with the respective Air Traffic Management (ATM) is performed to demonstrate the benefits of the MET information to the aviation community. The project also consists in transferring the knowledge gained in AvRDP to other WMO Members who need to enhance their aviation MET services as to meet the ASBU initiative.

Paris-CDG airport participates in AvRDP for winter weather in the Northern Hemisphere and two Intensive Observation Periods (IOPs) have been studied so far: Winter 2015-16 and Winter 2016-17.

Context and general background

Paris-CDG airport is located inland and mid-latitude in the Northern Hemisphere (49°N, 02°W), North-East from Paris. The world airport classification of 2014 (ACI World) ranked Paris-CDG as the 8th for the total passengers traffic (more than 63M) and the 4th for the international passengers traffic (more than 58M). During winter, its operations are often highly impacted by low ceilings and visibility due to fog and stratus clouds, and wintry conditions. These weather phenomena require precise and satisfactory forecasting to alleviate ATM services in their effort of avoiding airline delays, terminal area disruption and GA accidents. Thus, good MET information accuracy and a high refresh rate are crucial for ATM.

In case of threatening weather conditions, an emergency committee comprising representatives of Aéroports de Paris, the French civil aviation authority (DGAC), the airlines, and Météo-France gathers and decides what resources will need to be mobilised (manpower, machineries). As a response to Collaborative Decision Making (CDM) users' needs, an innovative solution was set for CDG operations, allowing common weather hazard awareness. It integrates the impact of weather on hub operations and is performed thanks to human expertise at a fine temporal resolution and a high refresh rate. Through this user-tailored system, Météo-France provides the latest science in forecasting techniques, including nowcasting data from the AROME-PI mesoscale model and from other data fusion products. The AvRDP winter IOPs allow demonstrating their contribution to the optimization and improvement of the weather awareness through the forecasters' and ATM work, and thus, the mitigation of adverse weather consequences on the Paris-CDG operations.
Météo-France’s NWP model, called AROME-PI, runs hourly at high temporal and spatial resolutions: 1.3km grid point and 90 vertical levels for a European domain centered around France. The forecasts range from +30min up to +180min with a 5 min refreshment rate and from +180min up to +6h with a 15 minutes refreshment rate. At each run time H, there is a data assimilation window of [H-10min, H+10min] and 20 minutes of processing (via a 3D-Var system) are needed before outputs are available. AROME-PI is non-cycled (initialization from the regional model AROME-France). It has a non-hydrostatic physical scheme and a complex microphysical scheme called ICE3 comprising 3 frozen hydrometeor categories. In addition to the common weather information available in AROME-France (such as temperature), this model includes several new diagnoses: supercell index, fog and hail probability, etc.

On-ground icing probabilities are calculated on Paris-CDG airport thanks to a statistical algorithm developed by S. Hugony. The inputs of the computation are the surface temperature, the humidity, the wind, and the nebulosity expertise by the forecasters. It provides an histogram of hourly on-ground icing probabilities up to 30 hours of forecast. Hence, ANTIGEL allows anticipating an eventual on-ground icing on the day before the icing occurrence.

Winter 2015-16 and winter 2016-17 were characterized by several events of fog and icing fog, as well as snowfall and industrial snowfall and a high-impacting episode of ice. Here, three case studies over the IOPs for winter are developed to enlighten the benefit of such tools for weather awareness:
- Surface and airframe icing on January 20th, 2016
- Wintry precipitation on March 5th, 2016
- Icing fog on December 29th, 2016

Surface and airframe icing

On-ground icing is one of the most cost-impacting threats at Paris-CDG. The airport manager Aéroports de Paris is responsible for aircraft de-icing operations, performed by service providers on 20 dedicated areas and with 50 de-icers. Hence, this phenomenon is predicted by the forecasters in the CDM@CDG tool. ANTIGEL, an on-ground icing probability model, provides more MET information to the forecaster for edition of the CDM@CDG base. It has proved its good accuracy and is often used during the winter season.

On January, 20th 2016, weather conditions were anticyclonic over France, conducive to cold conditions and clear skies in winter. Humidity patches from a decaying front lingered until January, 21st: favorable conditions for vehicle icing were gathered. Indeed, fog forecasts were issued by Paris-CDG forecasters for icing fog on January, 20th from 0235Z to 0650Z and on January, 21st from 0540Z to 1005Z. An accurate vehicle icing risk with a quite high probability of occurrence from January, 20th 21h up to January, 21th 4h was set in the CDM@CDG tool.

It allowed the airport manager to anticipate the de-icing operations of airframes, and the ATM to better manage disturbances of traffic. De-icing operations, numerous during these two days:
- 162 de-icing operations on January, 20th
- 128 de-icing operations on January, 21st

These operations caused considerable delays and costs during the period, as the airport departure capability decreased significantly (as shown on FIG1).
FIG1: Paris-CDG airport departure capacity from January, 20th 2016 at 0Z to January, 21st at 12Z. During fair periods, the mean airport departure capacity is shown (71 departures per hour)

The forecast of these threatening conditions was performed (among other products) thanks to the aforementioned on-ground airframe icing (rime, frost)-probability model, as shown on FIG2. It suggested a high risk of on-ground icing with a good chronology of the event.

This case study enlightens the interest of using tailor-made models to better forecast airframe icing and hence allow the ATM to better manage the de-icing operations.
Wintry precipitation

Although not daily at Paris-CDG, wintry precipitation (snowfall, graupel, ice) fall from time to time during winter, mostly from December to March. A snow plan is activated as soon as any weather-related risk becomes apparent. The CDM team meets and convenes to decide what resources will need to be mobilised (manpower, machinery). The runways, taxiways and aircraft parking stands are cleaned when they are unoccupied. These operations are under the responsibility of the airport manager, performed thanks to 174 snow-clearing vehicles (“snow trains”). The runways (depending on their length) can be cleaned in 20-30 minutes, during which the traffic on the runway is suspended, seriously reducing the airport capacity.

March, 5th is a good illustration of such snowy conditions on Paris-CDG: a front lingered over France during the whole night between the 4th and the 5th and the following day. LVP conditions occurred from 0430Z to 0515Z, and it snowed from 0330Z to 1100Z and there were graupel showers from 1600Z to 2030Z. These conditions led to the treatment of the runways from 0500Z to 0615Z, causing the reduction of the airport departure capacity down to 24 (the nominal rate is 71). Also, de-icing of 119 aircrafts was necessary to sustain safe travel conditions.

The snowfall risk was well anticipated by forecasters in the CDM@CDG tool (FIG3) until 10Z. An airport warning was also issued at 0200Z, forecasting snow between 0330Z and 1130Z, which exactly corresponded to the observed snowfall time.
FIG3: Weather predictions from the CDM@CDG tool updated on March, 05th 2016 at 00:20Z

This accurate forecast was performed thanks to Météo-France’s nowcast model AROME-PI, but also the regional model AROME-France (FIG4). Indeed, the run of March, 5th a 00Z of AROME-France showed a risk of snowfall at 03Z. The vehicle-icing model provided also a relevant information to the forecasters, hence, to the ATM-operators.

FIG4: Cloud snow fields (in red) from the AROME-France model. Run of March, 5th 2016 at 00Z, fields at 04Z and 05Z.
Icing fog

There are approximately 40 days of fog or freezing fog per year at Paris-CDG airport, most of them occurring during winter. When the horizontal visibility decreases down to 600 meters and/or cloud ceiling become less than 200 feet, the French ATM (DGAC) apply Low Visibility Procedures (LVP). These LVPs, issued in the early morning hours, allow avoiding incidents thanks to a better spacing out of the airplanes on the ground. This type of procedure cuts down the overall airport capacity by a factor of two or three. Hence, low visibility is one of the weather factors with the best prospects of improving from the perspective of ATM.

Calm and anticyclonic conditions lingered over France in the end of 2016. At Paris-CDG, it was associated with temperature inversions and negative temperatures during the whole day. It clearly appears on the forecast temperature profile at 06Z, associated with humid and freezing conditions at the surface.

As displayed on FIG5, the dominant visibility begun decreasing in the early morning of December 29th, until freezing fog was formed around 06Z. After a slight improvement during the day, thick fog is formed at dawn only to disappear several days later.

![FIG5: Number of vehicle de-icing operations (blue bars) and prevailing visibility (red line) at Paris-CDG platform on December 29th, 2016](image)

The icing fog of December 29th, 2016 triggered numerous decreases in the number of arrivals and departures at Paris-CDG airport (FIG6). To maintain safe flight conditions, a significant number of de-icing operations were necessary during the period (FIG5), which are
expensive and need to be well anticipated thanks to the forecaster’s expertise and NWP models.

![Diagram](image1.png)

**FIG6: Forecast (dotted line) vs. actual (solid line) number of departures (top) and arrivals (bottom) at Paris-CDG platform on December 29th, 2016. Local time.**

The freezing fog forming conditions were well identified by Meteo-France’s models, in particular AROME-France. However, the AROME-France runs of 00Z and 03Z pictured a drier surface air mass than the actual one. The run of 06Z of the nowcast model AROME-PI, on the contrary to the run of 04Z, suggested a risk of fog at 08Z over Paris area. It allowed the forecasters to correct the visibility data displayed in the aerogram of Paris-CDG platform. As shown on FIG7 before 06:35Z, only a risk of mist was forecast, and once the AROME-PI run of 06Z was available, the forecaster added a risk of freezing fog to the CDM@CDG tool.
Icing fog is one of the most threatening weather phenomenons for Paris-CDG operations and occurs quite regularly during the winter season. A better anticipation and alleviation of its consequences is required. That is why innovations are developed at 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.

**Conclusion**

This report illustrates the positive impact to the ATM operations of the extra information provided by state-of-the-art models such as Météo-France’s nowcasting model AROME-PI and ANTIGEL, the vehicle icing statistical model over a high-traffic airport during bad weather situations through the CDM@CDG tool.

A better management of flight arrivals and departures in case of LVP conditions, on-ground icing conditions, and snowy runways is hence allowed thanks to an improved assessing of the timing of such events and their severity.