Session 2 – Integration, use cases, fitness for purpose and service delivery

2.1 – In-cockpit & on-board MET capabilities

Aspects of weather information transfer to pilots.

Klaus Sievers, IFALPA, Canada
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Speaker: Klaus Sievers

Since the days of the Wright Bros., pilots recognize the importance of weather to safe flying. Getting modern weather information for planning, with regards to enroute conditions to landing and final parking, is part of every professional pilot´s work. This information-set should include appropriate, modern, colourful weather info for print-outs, for the eFB, for uplink enroute. Information about turbulence, convection, cloud height and volcanic clouds is extremely relevant. Unfortunately, such information-sets are rarely available in airline practice.
Looking back, Meteorologists have concentrated on building ever more complex and capable meteorological systems on Earth and in Earth orbit. The Met Systems provide, transform and transport data: gigabits/second, multi-terabyte storage banks. We have a veritable glut of data, which will get pushed into the aviation data-systems of the future. Names like SWIM, IWXXM and 4D DATACUBE are in use.
So, data is available, information is available but the relevant rules and regulations, which are necessary to co-ordinate Met around the globe, have not been adapted to allow the practical use of much of the data. WAFS datasets are available several times a day, but visualisation of the data is left to the so-called private sector. Transmission of these data to aircraft in flight and display on an eFB is certainly possible – but the rules to allow this are neither flexible nor practicable. Transport of bits and bytes may get the occasional nod from a regulator, but getting approval for operational use of such data by displaying them to pilots is another matter entirely. Getting approval for any new product out of research is extremely difficult – and that would include even the approval for use of a paper printout of such information.
Furthermore, enhanced efforts are needed in the continued education of pilots about modernMet ideas (uncertainty, ensemble-forecasting, and decision support tools).Forecasts and displays need to be improved in line with the exponential growth of computing-power and observational capabilities, e.g. in-situ measurements by aircraft.
In sum, innovative Met information is there, is available, but concentration on Data and their well-being led to stagnation in the development of information-displays and transmission to pilots. There is no standard for colour sigwx-charts, there is no standard for colour satellite pictures. Good, actionable information is not widely available in modern form to airline pilots.
According to findings of the 2016/2017 CAeM global survey on aeronautical meteorological service provision, the CAeM Newsletter of September 2017, there is a very wide variety, globally, in the organisation of weather information provision. This variety should not hinder the flow of modern weather into the hands of pilots. It is, however, well beyond the means of any organisation like IFALPA to affect improvements uniformly on a global scale - it is hoped that the WMO, as a global organisation, can enhance standards and drive developments to ensure that the available Met-data can be visualized so that pilots can fly safer, with improved situational awareness.

We don´t need more supercomputers – we need modern weather information, in the hands of pilots.

***Session 2** – Integration, use cases, fitness for purpose and service delivery*
2.1 – In-cockpit & on-board MET capabilities

Integration of weather forecast in the cockpit.

Florent Birling, GTD, Spain
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Speaker: Florent Birling

What are the pilot needs before the take-off and during the flight? During the last years airlines have worked on replacing the paper briefing by a digital solution compatible with devices such as their tablets. Static charts in pdf files completed progressively the electronic flight folder, which allowed a transition to a complete digital solution in tablets. With the widely spread of ground and satellite communication, the pilots are now requesting a more dynamic solutions with close to real time forecast and nowcasting of the meteorological phenomena. They are interested in getting the most recent updates of the meteorological information few minutes before the take-off from their iPad with 4G communication and even request updates from a connected EFB in the cockpit during the flight. Clear Air Turbulence, Convection, Icing, Ice cristals are the main worries of air crews who want to maintain and improve the safety and the comfort of the passengers
Having been attentive to the pilots need during the last 12 years, a SME designed, developed and implemented a new weather solution for the pilots named eWAS. Thanks to strategic partnerships, the company succeeded in proposing its innovative weather service word-wide and now the solution is implemented and used in operation in several major airlines in Europe and Asia.
The presentation provides an overview of new needs expressed by airlines and crews and exposes an example of integration of the new system eWAS into the whole flight management process as undertaken by the French airline Air France.
More details can be found on the Application web site www.ewas.aero.

Session 2 – Integration, use cases, fitness for purpose and service delivery

2.1 – In-cockpit & on-board MET capabilities

Automated in-situ Turbulence reports from Airbus aircraft.

Axel Piroth, Airbus, France
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co-author: A. Mermet

Speaker: Axel Piroth

A study published this year by Paul D. Williams showed that the amount of transatlantic wintertime clear-air turbulence in the atmosphere will increase significantly in all aviation-relevant strength categories as the climate changes. Other studies confirm this trend even if more analysis are required to have a global and complete picture of the turbulence occurrence in the coming years. In order to achieve this, the scientific community needs to improve its physical understanding of the generation of small-scale processes.

To achieve this, the capability to rely on real operational turbulence data detected from aircraft is a major opportunity This is the exact goal of the EDR project launched by Airbus.

The purpose of this project is to equip airbus aircraft with an algorithm which calculate the turbulence around the aircraft.

Among the several options that exist to characterise the turbulence, the EDR (Eddy Dissipation Rate) has been chosen to be compliant with the ICAO recommendation regarding turbulence detection. This parameter, which is independent of the type of aircraft which senses it, can be used on-board but also downlinked for several applications on the ground.

The algorithm has been defined, developed and implemented on board the aircraft.

Besides evaluation sessions with pilots on aircraft simulator enabled to determine severity thresholds associated to EDR values. That will have to be matured during real event situations

It is foreseen that, having a significant number of aircraft equipped with the EDR algorithm detection will enable at least two major improvements:

First the exchange of information between aircraft in order to improve pilots awareness about the turbulence occurrence around their position and their planned trajectory. This will help them to determine the areas to avoid and those which are safe and bring benefits to the airline in term of safety, passenger comfort and branding. Some preliminary results already exist thanks to about 40 airplanes that are equipped with EDR algorithm since almost a year. This data allow us to build some statistical representation of turbulence occurrence over Europe.

Secondly, the gathering of such data will be key to improve long and short term forecast of turbulence in order to have a continuous representation of turbulence phenomena and better anticipate and optimise airplanes trajectories taking into account avoidance of turbulence areas.

Therefore partnership with National MET service providers is a fundamental part of this project strengthening the improvement and the validation of turbulence forecast.

Session 2 – Integration, use cases, fitness for purpose and service delivery
2.2 – Terminal Area and Impact-based forecast

Terminal Weather Event Detection and Advisory Concept.

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Speaker: Robert Avjian

The lack of appropriate decision support tools at major airports and terminal approach control facilities requires traffic managers and decision makers to cognitively translate observed and forecast weather information into weather events that are then used to determine resource capacity. The impact of this problem on the United States National Airspace System (NAS) is that cognitive-based capacity determinations can lead to inefficient state changes or operations decisions. To address this issue, we consider two concepts, both contained in the Joint Planning and Development Office (JPDO) ATM-Weather Integration Plan Version 2.0 weather translation and weather threshold event.
Weather translation refers to the process of transforming raw weather observations and forecasts into expressions of weather that are operationally relevant to the NAS. The other class of weather translation is known as a weather threshold event. This type of weather translation takes observed or forecast weather parameters such as wind speed and direction, cloud heights and visibility and converts them, based on adapted, user-specified meteorological conditions, to specific operating states at the affected terminal element (airport or airspace). When the value of those parameters crosses an operationally-relevant threshold, a weather threshold event is said to have occurred.
Weather Event Detection and Advisory (WEDA) is an envisioned terminal area capability that evaluates specific atmospheric factors such as ceiling, visibility and wind conditions, and identifies weather events that may impact terminal flight operations and affect airport capacity. Airport capacity measures, which necessarily include the terminal airspace, are expressed in terms of airport arrival rate (AAR) and airport departure rate (ADR).
In June, 2016, the MITRE WEDA team visited the Atlanta Air Traffic Control Tower (ATL) and Atlanta approach control facility (A80) to interview traffic managers, supervisors and certified professional controllers (CPCs) to understand how they collectively use weather observations and forecasts to adjust Atlanta's AAR and ADR values. The WEDA team used this information to define rulesets and threshold values that would be used to provide WEDA advisories for the Atlanta Hartsfield Jackson International Airport (KATL). A WEDA Demonstration Capability (WDC), accessible over the internet using a standard web browser was developed and evaluated using tabletop simulation exercises at MITRE/CAASD with a subset of operational subject matter experts from Atlanta Tower and TRACON. The results of the tabletop exercises are presented.
In this paper, we describe
1) the WEDA concept that transforms raw weather into potentially actionable information,
2) the WEDA demonstration capability developed for the Atlanta terminal airspace and
3) the results of operational user evaluations.

Further WEDA development will focus on its application at additional airports in the NAS. The WDC will be revised based on future laboratory and field exercises. The relationship between WEDA and future releases of the NextGen Weather Processor (NWP), Common Support Services-Weather (CSS-Wx), Aviation weather Display (AWD) and potentially any airport demand DST associated with Terminal Flight Data Management (TFDM) will be explored.

Session 2 ***– Integration, use cases, fitness for purpose and service delivery***

2.2 – Terminal Area and Impact-based forecast

Translating Meteorological Observations into Air Traffic Impacts in Singapore Airspace.

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Speaker: Michael Robinson

A fundamental responsibility of air traffic flow management (ATFM) is to optimize airspace utility and efficiency while maintaining high operational safety standards. This is accomplished by implementing strategic plans and executing tactical decisions that prevent the occurrence or mitigate the impact of air traffic congestion. Congestion arises when imbalances occur between air traffic demand and capacity, either because of high traffic volume relative to nominal capacity or because of degradations to available capacity.

Airport and airspace resource capacity degradation occurs for many reasons, including equipment outages, staffing limitations for air traffic control, or sharing airspace with military operations. However, the most frequent and significant factor that limits air traffic capacity is adverse, aviation weather.

The MITRE Organization and the Civil Aviation Authority of Singapore (CAAS) are researching models to measure and predict air traffic demand and capacity in support of ATFM decision-making for the Singapore Flight Information Region (FIR) and beyond. A core challenge and focus of these efforts is translating Singapore's significant aviation weather phenomena (particularly convection) into air traffic impacts and subsequent reductions to airspace resource capacity (e.g., traffic flow, airspace sector). This challenge is exacerbated by the dynamic nature (and associated forecast challenges) of oceanic and monsoonal convection that frequently impinge on a Singapore air traffic operation. These weather impacts can be severe, given Singapore's nontrivial traffic demand. That demand on air traffic resources continues to rise, so the need to recognize and predict weather-induced capacity impact and congestion in support of proactive impact management is becoming a significant priority.

This paper will present research findings on models developed to translate meteorological observations of convective weather into air traffic impacts in Singapore airspace. Specifically, the paper will describe how two and three-dimensional convective weather encounters vs. deviations by aircraft in Singapore airspace were systematically evaluated to develop an objective likelihood field for weather avoidance. The paper will then demonstrate how the weather avoidance field can be applied to both the specific geometry (e.g., arrival, departure flows; airspace sectors) and the operational context (e.g., peak arrival periods, warning airspace limiting weather deviation options, direct airport impacts and runway configuration) of the Singapore operation to alert to weather impacts and its severity. A description for how these objective weather impact diagnoses will in turn be used to measure weather-induced capacity loss for key Singapore air traffic resources will also be provided.

This exploratory research proved valuable for uncovering the range of challenges and prioritized needs for establishing an air traffic management (ATM) – weather integration effort for airspace in the Asia Pacific region. This paper will highlight some of these challenges and opportunities for remediation, focusing specifically on what applied weather forecast requirements may be needed to transition new weather impact diagnostic capabilities to predictive decision support.

***Session 2** – Integration, use cases, fitness for purpose and service delivery*

2.2 – Terminal Area and Impact-based forecast

Probabilistic Winter Weather Nowcasting supporting Total Airport Managament.

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Speaker: Heikki Juntti

Winter Weather is a remarkable reason for delays and cancellation of flights. It influences to many airport procedures in Airside and Landside of airport. The SESAR program aims to improve efficiency of airport operations by Collaborative Decision Making (CDM) procedures. Essential part of that is sharing a common view of weather having influence to operators.

The Sesar 2020 Exploratory Research (ER) Project PNOWWA (Probabilistic Nowcasting of Winter Weather for Airports) is a joint effort of Finnish Meteorological Institute in Finland, DLR in Germany and Austro Control in Austria to create set of Winter Weather Nowcasting product prototypes to all airport operators, which can be used as a part of joint plan in Total Airport Management.

The PNOWWA project is producing methods for the probabilistic short-term forecasting of winter weather and enable the assessment of the uncertainty in the ground part of 4D trajectories. According to our user survey, probabilistic forecasts could be used in ATM applications to support operational planning in surface management and ATM (Air Traffic Management) decision making, thereby increasing airport capacity, shortening delays and promoting safety.

PNOWWA demonstrates very short-term (0-3h, "nowcast") probabilistic winter weather forecasts in 15min time resolution based on an extrapolation of movement of weather radar echoes and improve predictability of changes in snowfall intensity caused by underlying terrain (such as mountains and seas). Research demonstrations are conducted both offline and online. The demos were designed based on an extensive user consultation which analyzed user needs to ensure products are suitable to be integrated in various applications on the ATM side. The adjustment to user needs covers the most relevant parameters (visibility, intensity and snow depth) and operationally important thresholds of the selected parameters (e.g. heavy snowfall).

An online survey and face-to-face interviews were used to map the needs of probabilistic winter weather forecasts at airports. We focused on three user groups: runway maintenance, de-icing and TWR control. The demo forecasts were also given for the meteorologist serving these groups.

In the first demonstrations, very simple methods were used to determine the movement. As a first guess, method described by Andersson and Ivarsson, using 850 hPa winds from weather prediction model was used. Other more sophisticated methods are developed for use in the second demonstration in the coming winter.

For verification, we will show a few cases and some end-user feedback. Based on that demo has shown areas for further development and highlighted the importance of discussions between MET and ATM to found the optimum products to be most valuable for ATM.

Web pages of project are: http://pnowwa.fmi.fi

***Session 2** – Integration, use cases, fitness for purpose and service delivery*

2.2 – Terminal Area and Impact-based forecast

Data-driven influence model of weather condition in airport operational performance.

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Speaker: José Antonio Fernández Monistrol

Adverse weather conditions are a major cause of flight delays and cancellations each year. In Europe, the influence of meteorology on airport operations is a matter of everyday experience, but it is still lacking of quantitative models supporting decision-making processes. This study determines the relationship between airport meteorological conditions and different airport operational performance metrics. The aim is to incorporate the meteorological information into the ATM decision-making process by means of an integrated meteorological indicator, based on actual or forecasted data, to qualify the actual or expected situation.

For this study, both real meteorological data, based on the METAR reports, and different metrics of airport operational services (inefficiency during the approach to the airport, percentage of holdings, additional turn-around time, delays...) corresponding to more than three years at the main Spanish airports, have been analyzed. Considering meteorological parameters (temperature, dew point, direction and speed of the wind, precipitations, cloud height, visibility, and barometric pressure) different impact levels associated with the operation have been obtained, depending on the value of the set of metrics used to rank the airport service level.

The process followed in this research starts with empirical values both for the thresholds of the different meteorological parameters and the impact those on the operation, which allows the definition of the integrated meteorological indicator itself. These thresholds are then modified in an iterative process based on genetic algorithms, improving the thresholds in order to achieve a better relation with the airport performance metrics. The positive results obtained with this innovative approach show great potential for operational usage within the airport domain.

***Session 2* – Integration, use cases, fitness for purpose and service delivery**

2.3 – Collaborative decision-making, Air Traffic Flow Management, Network Management

The bridge from meteorological research to improved safety of air transport.

Jaakko Nuottokari, Finnish Meteorological Institute, Finland

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Speaker: Jaakko Nuottokari

Meteorological information and services supporting the various operations of air transport enable a safe, efficient and cost-effective operating environment for airspace users, air navigation service providers and air traffic management. The continuing pursuit towards an improved quality of observation, forecasting and decision support services is driven by an increasingly weather-sensitive society and growing impacts of hazardous weather events.

This talk will provide a brief overview of the field of aeronautical meteorological research by introducing organisations involved, global and regional strategies, impacts of weather on air transport, current state of the art in meteorological research and decision support systems serving air transport needs with a view of where the field should evolve next.

Research supporting air transport operations with the optimal use of weather information is a specialized field where advances are led by the needs of various airspace users. The creation and maintenance of long-lived teams of scientists and engineers working together to produce end-to-end solutions that meet the needs of the aviation industry is the key to the advancement of aviation weather while university research is typically shorter duration and typical does not result in operational systems.

From a global perspective, research is yet to be organised in a way that would focus on solving aviation issues beyond single research projects and/or programmes. There is a lot more the scientific community could do to develop tailored information to decision support systems used by the aviation sector, but it would require systematic investments and the establishment of research groups focusing on the applied science questions and technology transfer. This talk includes some examples of decision support system development topics with an outline of potential milestones for the consideration of the conference and is based on the author's experience from managing the Northern Europe Aviation Meteorology Consortium (NAMCON), leading SESAR projects, EUMETNET AVIMET Chairmanship, WMO CAeM ET-GOV membership and an extended scientific visit to NCAR in Boulder, USA in 2017.

***Session 2** – Integration, use cases, fitness for purpose and service delivery*

2.3 – Collaborative decision-making, Air Traffic Flow Management, Network Management

Harmonized high quality weather forecasts - Weather does not consider political borders.

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Speaker: Svenja Koos

The SESAR Deplyoment project “European Harmonised Forecasts of Adverse Weather (Icing, Turbulence, Convection and Winter Weather)” is an INEA funded project for the deployment of the European consolidated forecasts of adverse weather solution developed through SESAR WP11.2, at an operational level for use by the aviation community. Various aviation user communities are expected to realise benefits, which will in turn benefit passenger and cargo operational efficiency and safety. Several validation campaigns have been conducted successfully during the development phase.

The scope of the work is the implementation of schemes to consolidate forecasts of icing, turbulence, convection and winter weather of the participating Met Service providers (Deutscher Wetterdienst, Météo France, Met Office, Finnish Meteorological Institute). The intention is to arrange a harmonised figure of meteorology over Europe. The forecasts are based on either Numerical Weather Prediction model output or NowCasting approaches. It is the objective to integrate and process nationally produced forecast information from different Met service providers to provide a harmonised quality controlled single source forecast on aviation hazards with full European coverage where applicable.

The project coordinates and communicates with the whole EUMETNET community through the support of EUMETET EIG and considers the user requirements by support of EUROCONTROL.

There is a close coordination to the MET Information Exchange project “MET-GATE” to make these Met products available via user-tailored SWIM compliant services.

***Session 2** – Integration, use cases, fitness for purpose and service delivery*

2.3 – Collaborative decision-making, Air Traffic Flow Management, Network Management

Integration of Meteorological Data in the ATM System.

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Speaker: Eirc Bekker, South African Weather Services , South Africa
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"The cooperation between ICAO and WMO will result in a better integration of the meteorological information into the Air Traffic Management system as a key enabler to improving aviation safety, enhancing air navigation capacity and efficiency, reducing the impact of aviation on the environment and mitigating the impact of climate change and variability on aviation."

The ATM operational concept is a vision that describes how an integrated global ATM system should operate. Often the impact of weather phenomena on the ATM system is not taken into consideration at an appropriate level. This leads to delays and extra fuel burn by aircraft which could have been avoided.

Two major weather system dominates over South Africa in a year. In summer, the interior of South Africa is dominated by tropical weather systems characterized by severe thunderstorms. In winter, the mid-latitude weather systems dominates over the southern parts of South Africa bringing rain and strong winds. The effect of mid-latitude weather systems can also be felt in winter over the high-veld (inland plateau) where cold temperatures in the morning often result in prolonged periods of reduced visibility due to fog. It is believed that this weather phenomena could result in a reduction of up to 50% of airspace capacity.

The Central Airspace Management Unit (CAMU) based at O.R. Tambo International Airport is responsible for managing the flow and efficient trajectory of aircraft within the South African airspace. For this to be done effectively, accurate real time and weather predictions need to be provided by the South African Weather Service (SAWS).

Daily Airspace Plans (DAPs) are distributed by CAMU to the other affected ATM community members, primarily Aerodrome and Air Operators, informing them of capacity and demand, particularly at the three coordinated airports within South Africa. The DAP, one of CAMUs management tools, also informs the industry of constraints that are being experienced at these airports, as well as possible weather phenomenon that could be expected for the duration of the day.

The accuracy of the DAP allows the aviation industry to effectively plan around any constraints that are being experienced in the air or on the ground. The major benefit to the aviation industry is that delays can be put into effect while the aircraft is on the ground instead of being airborne and burning extra fuel due to possible holding and/or diversions.

CAMU and SAWS are ensuring that all weather predictions are accurately integrated into the pre, and tactical phases of the ATM System in a timely manner thereby ensuring that the aviation industry can effectively plan for their immediate and indeed, daily operations.

It is intended to present a paper explaining the advances already made in the area of collaboration and information sharing in this identified area of consideration, and to furthermore solicit increased participation in the benefits.

Session 2 – Integration, use cases, fitness for purpose and service delivery

2.3 – Collaborative decision-making, Air Traffic Flow Management, Network Management

TOPLINK/ECOsystem: New Decision Support services to reduce MET impact on Aviation.

Daniel Muller, THALES AIR SYSTEMS, France
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Speaker: Daniel Muller

The SESAR Large Scale Demonstration Project TOPLINK aimed at demonstrating the benefits for ATM stakeholders (ANSPs, Airlines, General Aviation, Airport operators) of the deployment of ECOsystem, a new System Wide Information Services Platform. This platform aims at elaborating a joint and consistent picture of the global Air Situation and its environment (especially meteorological), at computing dedicated KPIs and alerts for each user's profile, and at supporting anticipated decision-making processes. The trials were conducted with a panel of 15 organizations throughout Europe during the summer period 2016.

The trials demonstrated the high added value of combining weather information (MET), Aeronautical information (AIM) and flight information to support strategic & pre-tactical decisions, including:

- a positive impact on all targeted performance KPAs (fuel & cost efficiency, predictability, punctuality, airspace capacity, …)
- a better situational awareness resulting in reduced stress in abnormal / fast evolving situations; and
- increased safety through a better anticipation of unexpected events

Finally, the project has demonstrated that tangible results could be achieved (under some pre-conditions) in such Use Cases as:

- better tailoring of MET-induced regulations (ground delays) by ACC and Airports with an immediate impact on all Airspace Users; and
- better anticipation of MET-related issues for Airspace Users to more efficiently manage flight plans revisions, and avoid costly « last minutes decisions(e.g. late vectoring, diversion, holding…).

The platform is being industrialized and will in short term start delivering operational services to multiple clients (ANSPs, Airlines and Airport operators)worldwide.

***Session 2* – Integration, use cases, fitness for purpose and service delivery**

2.3 – Collaborative decision-making, Air Traffic Flow Management, Network Management

COLLABORATIVE DECISON MAKING@CDG

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speaker: Michel Landelle

Today Paris-Charles de Gaulle Airport handles over 65 million passengers and nearly 500,000 aircraft movements per year. An aircraft is landing or taking off every 30 seconds at peaks of activities... On the busiest days, an average of 200 passengers are arriving or departing every minute. This is an every minute challenge in coordination and management in a complex environment and that is why having an organization like the CDM is of essence.

This important term 'Collaborative Decision Making' covers many technological innovations but is the result of a simple idea: together we are stronger to deal with our common destiny. It is so simple that it took several years of maturation for each of the CDM Paris-Charles de Gaulle historical actors to take ownership.

For Paris-Charles de Gaulle, it started in 2004. In November 2010 a maturity milestone was reached, with the introduction of the label A-CDM by Eurocontrol. It embeds the data and tools of airlines' airport operator and air traffic control, and aims to optimize the flow to the runway, incorporating mainly local constraints. Aside many initiatives that have been implemented of the essentials is the weather web site developed by local teams of CDG meteorological station (which is operated by Météo France H24 /D365) called "AEROGRAMME". It gives us a prospective picture of the weather for the coming weeks and is updated in real time according to the need and forecasts.

Indeed "to work and decide together" means that the various partners should make it real every day. Easier said than done for each partner has his own a culture and history.

In the CDM control Room, the Weather Chief of staff and her deputy combined with Groupe ADP, AIR FRANCE and CDG ANSP (among others) colleagues, gather to share and decide the measures to take in order to preserve and ensure the strength and safety of the CDG airside operations. They all will share their information and knowledge to understand, analyze and eventually decide together to provide adequate responses, keeping in mind as much as possible the afterwards, aiming at a return to normal as soon as possible.

This organization, combined with technical and human resources of the Aéroports de Paris winter service, has been extensively tested during the winter of 2012/2013. It gave full satisfaction to Paris-Charles de Gaulle's customers. It wouldn't have been achieved without the close and strong support of Météo France.

The CDM@CDG is a great desire to succeed together. It has become our way of thinking, and every Paris-Charles de Gaulle projects is now subject to a CDM approach even beyond the airside point of view, leading to "CDG2.0 !"

Session 2 ***– Integration, use cases, fitness for purpose and service delivery***

2.4 – Trajectory-based operations (TBO), flight planning and user-preferred routing

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

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Speaker: PW Peter LI

The global air transportation will undergo significant upgrade in the next 15 year or beyond under the ICAO new Global Aviation Navigation Plan. To achieve this, aviation weather services will need to be enhanced. In particular, the nowcasting and mesoscale modelling services at or near the terminal area of an airport will need to be upgraded to support the tactical and pre-tactical stage of the aircraft trajectory. In this connection, WMO Commission of Atmospheric Science and Commission of Aeronautical Meteorology jointly take forward an Aviation Research Demonstration Project (AvRDP) in 2015-2018 with a view to demonstrating the capability of nowcasting and mesoscale modelling techniques and providing a 'fast-track' transfer of the research results into operational applications. The goal is to facilitate the national meteorological services under WMO to enhance their aviation weather services to provide sustainable high-quality services to support the safety, efficiency and regularity of air traffic management worldwide.

The objectives of the AvRDP are (i) to conduct research in advanced observation, nowcasting and mesoscale modelling at a few selected high density international airports to demonstrate the Meteorological (MET) capabilities in particular nowcasting and high resolution mesoscale modelling; (ii) to collaborate with the respective Air Traffic Management (ATM) to translate the MET information into ATM-impact information with a view to demonstrating the benefits of the enhanced MET information in ATM; (iii) to transfer the knowledge gained in AvRDP to other WMO Members who need to enhance their aviation MET services. To study different high impact weather at different locale with different climatological conditions, several airports at different continents participate in the AvRDP, namely, Charles de Gaulle Airport, Johannesburg Airport, Hong Kong International Airport, Shanghai Hongqiao Airport, Toronto Airport and Iqaluit Airport initially. The AvRDP is conducted in 2 phases: Phase I from summer 2015 till summer 2017 focusing mainly on the MET science aspect; Phase II from summer 2016 onwards focusing on the translation of MET forecast elements, qualified with uncertainty and confidence information, into ATM operational impacts, and the communication of such information to users for the improvement of their decision-making. Close collaboration between MET and ATM and other relevant aviation stakeholders is obviously critical in generating useful outcomes from the AvRDP. A few airports have already entered Phase II and discussion on MET-ATM translation is being studied. The Meteorological Services for Terminal Area (MSTA) information will finally merged with meso- or global scale NWP information to generate seamless gate-to-gate Trajectory Based Operation (TBO) information. To this end, WMO has plan to extend the AvRDP into an inter-commission core project. This paper will brief the progress and the future development of the AvRDP.

***Session 2* – Integration, use cases, fitness for purpose and service delivery**

2.4 – Trajectory-based operations (TBO), flight planning and user-preferred routing

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

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Speaker : Pauline Jaunet

The Aviation Research and Demonstration Project (AvRDP) aims at demonstrating, developing, and quantifying the benefits of nowcasting aviation services for the terminal area, focusing on high impact weather. Several airports participate in the AvRDP, including Paris-Charles-de-Gaulle Airport in France for two IOPs concerning wintry weather threats. Indeed, its operations are often highly impacted by low ceilings and visibility as well as runway contaminants (snowfall, ice) and on-ground and vehicule icing.

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 CDM users' needs, an innovative solution was set for CDG operations, allowing a 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 two avRDP winter IOPs, which occured during winter 2015-16 and winter 2016-17, allow to demonstrate the contribution of nowcast data to the optimization and improvement of the weather awareness through the forecasters' work, and thus, the mitigation of adverse weather consequences on the Paris-CDG operations.

Session 2 – Integration, use cases, fitness for purpose and service delivery

2.4 – Trajectory-based operations (TBO), flight planning and user-preferred routing

The Remote Oceanic Meteorology Information Operational (ROMIO) Demonstration.

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The Federal Aviation Administration (FAA) Next Generation (NextGen) Weather Technology in the Cockpit (WTIC) program is sponsoring an operational demonstration to evaluate the feasibility to uplink convective storm products to commercial aircraft flying routes over remote, oceanic regions for display on an electronic flight bag (EFB). The effort is called the Remote Oceanic Meteorology Information Operational (ROMIO) demonstration and is a collaborative effort between the FAA, the weather research community, the airlines and ground-to-air communications providers. The ROMIO will develop and demonstrate operational strategies for the use of rapidly updated Cloud Top Height (CTH) and Convective Diagnosis Oceanic (CDO) products on the flight deck, in the Oceanic Air Route Traffic Control Centers (ARTCC) and as part of Airline Operations Center (AOC) flight dispatch operations. Participating airlines include Delta Air Lines, United Airlines and American Airlines. The domain for storm product creation is contained by the scanning area of the Geostationary Operational Environmental Satellite (GOES) East and West satellites. Routes to be flown are between the continental United States (CONUS) and South America, Caribbean, Australia, and South Africa, among others. A select number of online pilots will participate in the demonstration. The ROMIO demonstration will begin in the fall of 2017 and be conducted for a year. During the demonstration, feedback from pilots, airline operations center dispatchers and Oceanic ARTCC Air Traffic Controllers will be solicited to ascertain the costs and benefits associated with providing realtime, rapidly updated graphical information on convective structure to them.

In this paper, the ROMIO demonstration purpose and goals will be described along with the communications infrastructure, the product displays, the weather products and the feedback mechanism. Preliminary observations will be presented as the demonstration will have a few weeks of operations by the time of the conference.

***Session 2* – Integration, use cases, fitness for purpose and service delivery**

2.4 – Trajectory-based operations (TBO), flight planning and user-preferred routing

Integrated Wind and Turbulence Forecasts for Automated Flight Route Planning.

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With recent improvements in observational techniques and computer capabilities in the Numerical Weather Prediction (NWP) models, the performance skill in forecasting upper-level winds has been increased continuously, which provides huge benefits for the aviation industry. For example, the average wind speed errors near the jet stream have decreased by about 45% from 13 to 8 m/s, which gives less uncertainty in both head and tail winds for long-haul flights, enhancing efficient flight route planning and reducing extra fuel consumptions (Ralph 2016). These improvements in wind forecasts, combined with the application of the multi-diagnostic method of the Graphical Turbulence Guidance (GTG; Sharman et al. 2006) have led to better aviation situational awareness and flight planning.
This paper introduces an example of the integrated wind and turbulence forecasts for automated flight route planning with wind-optimal and lateral avoidance trajectory modeling, which is more applicable for the most important and vertically deep weather hazards like Convectively Induced Turbulence (CIT) and Mountain Wave Turbulence (MWT). An example is provided for a case on 7 Sep 2013, for which a convection-permitting scale (dx = 3 km) high-resolution NWP model captured the background winds and convective clouds very well. Time-lagged ensembles of the GTG-like forecasts give laterally wide and vertically deep areas of potential turbulence encounters, which is applied to the flight trajectory model for a single flight route between the Los Angels International Airport (LAX) and John F. Kennedy International airport (JFK). As a result, timely different maneuvers of the Lateral Turbulence Avoidance Routes (LTAR) along the Wind-Optimal Route (WOR) from LAX to JFK illustrate the idea of trade-offs that can be made between total flight time/fuel consumption (efficiency) and lateral turbulence avoidance (safety). Other examples using the global NWP ensemble-based wind and turbulence forecasts for long-haul international flight route planning will be also shown.

***Session 2* – Integration, use cases, fitness for purpose and service delivery**

2.4 – Trajectory-based operations (TBO), flight planning and user-preferred routing

Flight Execution and Route Adaptation Considering Multiple Weather Hazards.

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Safety and efficiency are key factors for air traffic management. Both are strongly dependent on the environment and may be impacted by any disruptions caused by adverse weather or other airspace constraints. Today's management of air traffic is heavily geared towards avoiding areas of convective storms. Other weather hazards such as turbulence and icing are not as prominently featured in the daily planning process and dealt with ad hoc during flight execution as needed. Future trajectory-based operations, however, require an overall integration of atmospheric hazards which is enabled by the DIVMET weather avoidance tool that is applied here. The work to be presented aims to reveal characteristic consequences of a multiple hazard consideration in aircraft routing and flight execution. Simulations are based on a set of great-circle routes that are impacted by atmospheric hazards in different weather situations – e.g. a frontal system situation vs. air mass convection. The impact of each hazard type in those weather cases as well as the routing effects of its consideration in the avoidance process will be discussed.

Session 2 – Integration, use cases, fitness for purpose and service delivery

2.4 – Trajectory-based operations (TBO), flight planning and user-preferred routing

User Requirements for En-route Hazardous Weather Information.

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Hazardous weather not only impacts the safety of the aviation system but also efficiency and regularity. Under the current International Civil Aviation Organization (ICAO) system, Meteorological Watch Office issues SIGMET for its own airspace to alert the airlines and pilots of the potential hazardous weather. This however could easily lead to discontinuities across airspace boundaries due to difference in issuing time, forecast method, warning area, to name a few. There is thus a strong and long-standing need from users for a harmonized, phenomenon-based enroute hazardous weather information. The task to develop the next generation harmonized, phenomenon-based enroute hazardous weather information is being undertaken by the Regional Hazardous Weather Advisory Centre (RHWAC) workstream of Meteorological Information Service Development (MISD) Working Group under the Meteorological Panel of ICAO.

User needs analysis is a standard phase in commonly accepted system engineering practice. The goal of user needs analysis is to define the need for a new system or information systems and is an important step in developing the functional and performance requirements of the service providers. The users of enroute hazardous weather information include operators (which includes Airline Operations Centres, Dispatchers and Flight Crew) and Air Traffic Management. Each user may use the information in a different way with different emphasis. The next generation of harmonized, phenomenon-based enroute hazardous weather information should also align with the Aviation System Block Upgrade (ASBU) methodology and be integrated into the System-wide Information Management (SWIM) environment. Thus in establishing the next generation harmonized, phenomenon-based enroute hazardous weather information, a user needs analysis was conducted. After collecting the high level user requirements, the more detailed user requirements were collected through web-based questionnaires. The analysis of user requirements is currently being undertaken. This paper will present some initial findings of the user needs analysis. Apart from the survey results, this paper will also present an effort, namely the Operational SIGMET Coordination, now operating in a few MWOs in Asia to showcase an approach to achieve the issuance of harmonized, mainly convective, hazardous weather information for the region.

Session 2 ***– Integration, use cases, fitness for purpose and service delivery***

2.4 – Trajectory-based operations (TBO), flight planning and user-preferred routing

An illustration of the practical use of operational real-time geostationary satellite data for strategic and tactical flight planning.

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We present an analysis of the fitness of geostationary near-real-time satellite cloud property observations of the EUMETSAT SEVIRI satellite data for improving strategic and tactical flight planning. For this, we use historical SEVIRI satellite cloud observations from the Cloud Physical Properties algorithm and combined them with a small set of realized flight paths between Frankfurt (Germany) and Windhoek (Namibia) in 2008.

Flight paths are analyzed according to their tactical maneuvers in relation to observed clouds and clouds systems, and in relation to general aviation guidelines for navigating thunderstorms and cloud systems.

Results show that aircraft navigation follows these guidelines, which has the consequence that flights frequently enter mesoscale convective systems over equatorial Africa. Such encounters pose a threat to safety, reduces passenger comfort, while possibly also increasing fuel consumption. However, the analysis also shows that such encounters could have largely been avoided. Satellite data on the extent of these equatorial convective systems as well as possible “safe” corridors between cloud systems would have been available with sufficient lead times to allow for strategically changing the flight path and steer the aircraft either around the cloud systems or towards “safe” corridors between cloud systems.

We then further discuss what this suggests for the potential of such a system system using satellite measurements, as well as its pros and cons. We will also briefly evaluate monetary savings, which are estimated to be potentially in the order of many billions of US$ globally.

Finally we will briefly address the question of what is currently achievable based on operational geostationary satellite measurements, what expectations are with regard to future satellite missions and satellite data products as well as global coverage, and provide recommendations for additional research, field tests, development of satellite cloud information algorithms and operational services.

Session 2 – Integration, use cases, fitness for purpose and service delivery

2.4 – Trajectory-based operations (TBO), flight planning and user-preferred routing

Recommendations on trajectory selection in flight planning based on weather uncertainty.

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Speaker: Philippe Arbogast

In the world of aviation, Trajectory Prediction (TP) is currently mostly based on deterministic meteorological forecasts and thus does not take into account the probabilistic information available from an Ensemble Prediction System (EPS). One of the main aims of the IMET project was to quantify the predictability of flight planning systems by exploring the impact on TP output of ensemble weather forecast (EWF) generated by the EPS. Here, we use Probabilistic TP (PTP) defined by running a TP system n times with n being the number of members in the EWF. This allows an ensemble of trajectories to be created, which provides uncertainty information on flight duration and trip fuel cost. The information can be used to support decision making regarding the predicted trajectory. We demonstrate that the three state-of-the-art EPSs used within the IMET project are all capable of capturing relevant weather events observed from a large data sample of AMDAR measurements , thirty-six hours in advance of take-off.

Session 2 – Integration, use cases, fitness for purpose and service delivery

2.4 – Trajectory-based operations (TBO), flight planning and user-preferred routing

Climate-optimised aircraft trajectories based on advanced MET service for sustainable aviation.

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Speaker: Sigrun Matthes

Comprehensive assessment of the climate impact of flight movements is of increasing interest to the aviation sector as a requirement for identifying climate-optimal aircraft trajectories when developing strategies for sustainable aviation. Climate impact assessment needs to quantify impacts of CO2 and non-CO2 emissions, comprising in particular effects of contrail-cirrus, and nitrogen oxides on atmospheric ozone and methane. However, such comprehensive environmental impact information is generally not available during flight planning and generation of such data is not yet operational practice. Hence, the purpose of this study is to present a concept how such information can be made available via climate and environmental change functions (ECFs), which have the potential to serve as an interface to air traffic management. The work presented here relates to the SESAR2020 Exploratory Research project ATM4E (Air Traffic Management for Environment) which aims to develop MET services required for climate-optimisation, as well as to present a methodology which allows to establish a multi-criteria environmental impact assessment directly in the flight planning process, and to study changing traffic flows due to environmental optimization.

In the light of collaborative decision-making this MET service concept initially developed for climate optimisation of aircraft trajectories is expanded to a full environmental assessment, by representing additionally air quality and noise impacts by distinct environmental change functions. This simultaneous provision and integration of environmental change functions via advanced MET services enables to perform a multi-criteria environmental assessment during trajectory planning. For a use case climate-optimised aircraft trajectory, we present the mathematical formulation of the objectives functions required for environmental assessment and optimisation of aircraft trajectories. In that context we present ideas on future implementation of such advanced meteorological services into air traffic management and trajectory planning by relying on ECFs. These ECFs represent environmental impact due to changes in air quality, noise and climate impact.

In a case study for Europe prototype ECFs are implemented and a performance assessment of aircraft trajectories is performed for a one-day traffic sample. For a single flight fuel-optimal versus climate-optimized trajectory solutions are evaluated using prototypic ECFs and identifying mitigation potential leading to the identification of a Pareto-front relating climate impact mitigation potential with economic costs. The ultimate goal of such a concept is to make available a comprehensive assessment framework for environmental performance of aircraft operations, by providing key performance indicators (KPIs) on climate impact, air quality and noise, as well as a tool for environmental optimisation of aircraft trajectories. When developing future sustainable aviation, a quantitative validation of environmental performance requires an expansion of currently defined environmental KPIs.

Having available such advanced MET service for the use case climate-optimisation would allow planning of climate-optimised trajectories during the different phases of flight planning, as well as studying and characterising changes in traffic flows due to environmental optimisation and associated trade-offs between distinct strategic measures.