



**WMO Aeronautical Meteorology Scientific Conference 2017**

**6 - 10 November 2017**

**Centre International de Conférences - Météo-France - Toulouse - France**

# Book of Short Abstracts

**ORAL SESSIONS**



**THALES**





# WMO Aeronautical Meteorology Scientific Conference 2017

6 - 10 November 2017

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## Session 1 – Science underpinning meteorological observations, forecasts, advisories and warnings

### 1.1 – En route phenomena

#### 1.1.1 – Ice crystal icing, and airframe icing research

## A High Ice Water Content (HIWC) Nowcasting Trial Exercise for Enhanced Situational Awareness and Decision-Making Support.

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Speaker: Julie Haggerty  
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Ingestion of large amounts of ice particles by jet engines, known as ice crystal icing (ICI), appears to be the culprit in over 200 engine power-loss and damage events during the past two decades. Typically these events have occurred at high altitudes near large convective systems in tropical air masses. In recent years there have been substantial international efforts by scientists, engineers, aviation regulators and airlines to better understand the physical processes, solve critical engineering questions, develop new certification standards and develop mitigation strategies for the aviation industry.

One area of research has been the investigation of nowcasting techniques to identify potential areas of high ice water content (HIWC) and enable the provision of associated alerts to the aviation industry. The Algorithm for Prediction of HIWC Areas (ALPHA) was developed by the US National Center for Atmospheric Research (NCAR) with sponsorship from the United States Federal Aviation Administration (FAA). ALPHA uses satellite data, numerical weather prediction (NWP) model data, and ground based radar data (where available) as input, and applies fuzzy logic membership functions to blend data in a way that maximizes the strengths of each data set. In-situ observations of ice water content from research aircraft during a series of field experiments provided a data set for optimizing ALPHA using machine learning techniques. Verification with an independent data set showed a high probability of detection, but with a significant false alarm rate. Work to further improve the ALPHA algorithm is ongoing.

A joint 2-year effort by the Australian Bureau of Meteorology (BOM) and NCAR, with support by the FAA, explores options for products that best support airline operations and promote development of an international capability for HIWC detection and forecasting. Under this effort an experimental version of ALPHA will be implemented at the BOM over a region across the north of Australia where there is frequent deep tropical mesoscale convection and a high incidence of ICI events. ALPHA will be supported during an initial trial period spanning the Australian summer monsoon season (January – March 2018). Aviation industry stakeholders in the region, including BOM forecasters and airlines, will have access to the HIWC experimental product. Arrangements for obtaining standardized feedback from stakeholders are underway. A second trial period is planned for the monsoon season of 2019.

It is expected that evaluation of findings from this exercise will provide insight on further improvements to the ALPHA algorithm. In addition, results are expected to inform a decision on provision of a fully operational HIWC nowcasting product and progress the development on an international capability for HIWC detection and forecasting.

This research is in response to requirements and funding by the Federal Aviation Administration (FAA). The views expressed are those of the authors and do not necessarily represent the official policy or position of the FAA.





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## Session 1 – Science underpinning meteorological observations, forecasts, advisories and warnings

### 1.1 – En route phenomena

#### 1.1.1 – Ice crystal icing, and airframe icing research

### The use of RDT in the HAIC project.

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The European FP7 (Seventh Framework Program) HAIC (High Altitude Ice Crystals) 2012-2017 project aims at characterizing specific environmental conditions in the vicinity of convective clouds that can lead to aeronautical events linked to high-altitude mixed phase and glaciated icing.

RDT (Rapidly Developing Thunderstorm) is a software developed by Météo-France in the framework of NWCSAF (Satellite Application Facility for Nowcasting). RDT detects, tracks and characterizes convective systems.

In the framework of the HAIC project, the RDT has been operated by Météo-France and provided over the different fields campaign on an operational basis through dedicated processing chains. The RDT was operated for various satellites and domains: MTSAT for the first HAIC campaign (Darwin, 2014), MSG for the second one (Cayenne, 2015) and Himawari-8 and Meteosat 7 for the last one (Darwin/La Réunion, 2016).

First objective was to target the convective areas for the research planes. Thus RDT was used by forecasters of each campaign for the meteorological ground-support. RDT outputs were also adapted to be up-linked to the research planes thanks to the Planet system developed by Atmosphere Company (2015 and 2016 campaigns). This development allowed to enhance for the pilots the vision of surrounding convective areas.

Second objective was to study with the measurement-campaigns data how far RDT can be used to detect high IWC (Ice Water Content) areas. Qualitative and quantitative studies provided reasonably good results, especially in terms of probability of detection. In the figure one can see high IWC value inside a convective cell. RDT reached the level 5 of TRL (Technology Readiness Level) procedure used in the HAIC project to assess the degree of maturity of a technology. A comparison of RDT output with Low Earth Orbit satellites retrieval of IWC risk has also be performed.

Considering the good performances of RDT, the last NWCSAF release of the product (v2016) includes an attribute describing IWC risk inside each cell.

#### Acknowledgement:

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#### 1.1.1 – Ice crystal icing, and airframe icing research

### Satellite Detection and Nowcasting High-altitude Ice Crystals.

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Ice crystal icing (ICI) condition refers to aircrafts experiencing icing inflight in high altitude due to high concentration of large or small ice crystals. This type of en-route weather phenomenon may cause temporary engine power loss or damage to the blades. Due to their very small size, the presence of ice crystals could neither be noticed visually by pilots nor detected effectively by on-board radars.

In theory, high-altitude ice crystals (HAIC) are thrown into upper air by deep convection and carried downwind. With the emerging of next-generation meteorological satellites, detection and alerting of HAIC associated with deep convection has become feasible. We have developed an algorithm utilising selected infrared channels of the Himawari-8 satellite for identifying possible regions which may carry sufficiently small ice particles near deep convection. Here ICI incidents are characterised by a sharp increase in static air temperature (SAT) despite constant flight altitude. To identify the most relevant channels, Machine Learning technique, e.g. Random Forests, was applied to the multi-channel Himawari-8 data, which were then ranked by their relative skill. The split windows technique was then applied to the most relevant satellite channels:

High clouds identified by Band 13 (10.4 micrometer)

Overshooting tops detected by Band 09 (6.9 micrometer) and Band 13 (10.4 micrometer)

Dense ice clouds detected by split window Band 12 (9.6 micrometer) and Band 13 (10.4 micrometer)

Small ice particles detected by split window Band 07 (3.9 micrometer) and Band 13 (10.4 micrometer) during daytime

The algorithm was verified using en-route flight measurements provided by airlines with encouraging results. Using aircraft data collected in 2015 and 2016, the algorithm yielded a probability of detection of 0.65, a false alarm rate of 0.12, and true skill statistics of 0.53.

For movement prediction of the ICI region, we used the satellite motion field vectors derived from two consecutive satellite images to advect the HAIC field. Susceptible HAIC areas are marked using polygons, paving the way for easy transmission to airlines as well as future uplinking onto cockpits whenever the uplink capability becomes efficient. This paper presents the algorithm, its performance, as well as the on-going work on nowcast/forecasting of ICI for the aviation community. Additionally, the feasibility of HAIC forecasts based on application of the split windows technique to simulated multi-channel satellite radiances, generated by high-resolution NWP, would be demonstrated, enabling the blending of detection- and prediction-based methods for seamless ICI alerting.





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#### 1.1.1 – Ice crystal icing, and airframe icing research

## Signatures of supercooled liquid water drops in dual-polarization observations measured by ground-based radars.

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Speaker/ Clotilde Augros

Dual-polarization observations can be particularly helpful in diagnosing ongoing microphysical processes in precipitation, as they provide valuable information about particle sizes, shapes, composition, and orientations. These measurements include reflectivity at horizontal polarization ZH, differential reflectivity ZDR, differential propagation phase shift  $\Delta\text{DP}$  and half its range derivative specific differential phase KDP, as well as the copolar correlation coefficient  $\text{Rho}_{\text{HV}}$ . The focus of this study is to examine the potential of these observations for the detection of supercooled liquid water in clouds, which is of great interest for aircraft icing hazard monitoring.

Dual-polarization observations measured by the Plabennec operational C-band polarimetric radar were examined together with in-situ observations from an aircraft campaign where 35 flights sampled supercooled liquid water conditions during the winter 2014-2015. The analysis of the dual-polarization variables is explored using quasi-vertical profiles (QVPs: Ryzhkov et al. 2016) of radar observations. With the QVP technique, data from a given elevation angle scan are azimuthally averaged and the range coordinate is converted to height. This representation of the radar observations helps analysing the vertical distribution as well as the temporal evolution of the microphysical properties of hydrometeors in case of stratiform and relatively homogenous precipitation.

Results reveal important insights into the cloud microphysical processes that can be associated to the presence of supercooled liquid water. A case will be analysed in detail, where enhanced Kdp values were observed in the  $-3^{\circ}\text{C}$  to  $-8^{\circ}\text{C}$  temperature range, just above a layer associated to a minimum of Zdr, where the aircraft reported supercooled liquid water. Such signatures were also observed in recent studies (Sinclair et al, 2016; Kumjian and Lombardo, 2017), where the enhancement of Kdp was associated to the presence needles, attributed to secondary ice production or “Hallet Mossop” process (Hallet and Mossop, 1974).

These first results suggest that the analysis of the vertical distribution of Zdr and Kdp using the QVP technique could be used in real time in order to indicate regions with potential aircraft icing hazard.

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Ryzhkov, A., P. Zhang, H. Reeves, M. Kumjian, T. Tschallener, S. Trömel, and C. Simmer, 2016: Quasi-Vertical Profiles—A New Way to Look at Polarimetric Radar Data. *J. Atmos. Oceanic Technol.*, 33, 551–562, <https://doi.org/10.1175/JTECH-D-15-0020.1>

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## Session 1 – Science underpinning meteorological observations, forecasts, advisories and warnings

### 1.1 – En route phenomena

#### 1.1.1 – Ice crystal icing, and airframe icing research

## An operational geostationary satellite data product for detecting high ice water content.

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Speaker: Jos de Laat

We present a newly developed high ice water content mask (High IWC) based on measurements of the cloud physical properties (CPP) algorithm applied to the geostationary Meteosat Second Generation (MSG) Spinning Enhanced Visible and Infrared Imager (SEVIRI). The High IWC mask was developed within the European High Altitude Ice Crystals (HAIC) project for detection of upper atmospheric high IWC, an important parameter associated with the occurrence of In-Flight Icing, a known aviation hazard.

The High IWC Mask is provided in near-real time for the geostationary SEVIRI satellite (latency 30-45 minutes), which covers the Euro-African Earth Disc with a spatial resolution of 3x3 km (sub-satellite) to approximately 10x10 km at the edge of the disc view. Evaluation of the mask against both in situ measurements and satellite data reveals that the High IWC Mask is well capable of identifying atmospheric scenes with high IWC (IWC values > 1 g/m<sup>3</sup>) with a Probability of Detection of 60-80 % depending on the altitude of where the IWC is located.

A detailed analysis of one year of satellite measurements further indicates that the rate of detection can be improved by considering the height of the High IWC content. Combined, the Probability of Detection can be improved to better than 95%, in particular for High IWC at or above commercial aviation cruising altitudes. Improved detection comes at the price of more false detection, i.e. scenes identified by the High IWC mask that do not contain IWC > 1 g/m<sup>3</sup>. However, the large majority of these detections still contain IWC values between 0.1-1 g/m<sup>3</sup>. Considering that such scenes are not necessarily true false detection because the IWC values are still high, the performance of the CPP High IWC mask is excellent.





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**1.1 – En route phenomena**

**1.1.2 – Turbulence research**

## Turbulence forecasting with the ICON model @DWD: overview, cases and verification.

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Speaker: Tobias Goecke

The forecasting of aviation turbulence at DWD is based on Eddy Dissipation Parameter (EDP) naturally emerging from the turbulence scheme within the ICON model. Therefore some additional turbulent sources beyond the usual boundary layer processes have been included: subgridscale orography, convection and horizontal wind shear. Cases with turbulence incidents will be considered to exemplify these different sources in practice. In addition we present first results of a one year verification against commercial air-craft measurements.







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#### 1.1.2 – Turbulence research

## Global aviation turbulence forecasting using the Graphical Turbulence Guidance (GTG) for the WAFS Block Upgrades.

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Speaker: Robert Sharman

The Graphical Turbulence Guidance (GTG) is a turbulence forecast process whereby operational NWP model output (either deterministic or ensembles) is used to diagnose turbulence likelihood, globally, through an ensemble of prescribed physically-based indicators. The strategy is to compute a set of diagnostics that identify regions of strong spatial gradients, and using an empirical mapping technique to convert these indicators into an equivalent energy dissipation rate to the 1/3 power (EDR). This atmospheric turbulence metric is the International Civil Aviation Organization (ICAO) standard for aircraft turbulence reporting and thus provides a convenient basis for verification. Deterministic forecasts are provided using the ensemble mean of many computed turbulence diagnostics. This methodology is also the basis for the current operational (<http://aviationweather.gov/turbulence/gtg>) CONUS Graphical Turbulence Guidance (GTG) algorithm.

The ICAO has requested that the two World Area Forecast Centers (WAFC Washington at NOAA/Aviation Weather Center, and WAFC London at the UK Meteorological Office) provide automated and consistent grid information of en route weather hazards, called World Area Forecast System (WAFS) to global aviation users for strategic flight planning (06-36 hrs ahead). The current WAFS turbulence product provides uncalibrated turbulence potential. The WAFS Block 0 upgrade scheduled for 2018-2019 will replace the current uncalibrated product with global GTG EDR forecasts (G-GTG), using global NWP models provided by both WAFCs, with the final output from the two centers merged to provide one consistent turbulence forecast to the users. Clear-air and mountain wave turbulence sources are identified, although convective sources are more problematic due to the difficulty of coarse-resolution models to correctly capture convection. Probabilities may be developed from the diagnostic ensemble or from the NWP ensemble or both. It is envisioned that this would be the basis of the WAFS Block 1 upgrade that would provide probabilities of exceedance for selected EDR thresholds.

This talk describes the application of G-GTG in support of the WAFS requirements. Verification results are provided based on comparisons to aircraft in situ EDR observations and verbal pilot reports (converted to EDR) to obtain statistical performance metrics for both the deterministic and probabilistic G-GTG output.

“This research is in response to requirements and funding by the Federal Aviation Administration (FAA). The views expressed are those of the authors and do not necessarily represent the official policy or position of the FAA.”







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**1.1 – En route phenomena**

**1.1.2 – Turbulence research**

## A clustering method for diagnosing turbulence from MADIS database observations and derived fields from a high resolution NWP model.

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Speaker: Juan Simarro Grande

When pairing atmospheric turbulence measures from aircrafts with numerical model fields some difficulties arise, due to the intermittent and chaotic nature of turbulence, the lack of a dense network of observations and the granularity of some fields among other reasons. In this work we propose a new method to pair turbulence observations from airplanes and derived fields values from numerical models. The method is based on clustering the turbulence observations, which are near from each other in an important number of cases, defining a proper distance between them. Besides, each cluster is paired with the values of the derived fields within the same neighborhood as the observational cluster. We evaluate a number of derived fields as turbulence predictors, and construct an index from the best of them, using the logistic regression method. The NCEP MADIS database has been used to get the observations, whereas the HARMONIE-AROME model was used to obtain the derived fields.





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**Session 1 – Science underpinning meteorological observations, forecasts, advisories and warnings**

**1.2 – Wider Terminal Area**

**1.2.1 – Significant convection research**

## The short-time forecasting and nowcasting technology of severe convective weather for aviation meteorological services in China.

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Speaker: Xinhua Liu

Due to the increasing demand of the aviation meteorological service in the short-time forecasting and nowcasting of the disastrous weather, especially the severe convective weather, China's National Meteorological Center (NMC) has developed short-time forecasting and nowcasting techniques which can be applied to aviation meteorological services. These techniques are introduced in this article. They include probability-matching calibration method, neighborhood approach, multi-model integration method for precipitation and radar echo, time-lag precipitation correction method, precipitation forecasting method based on Titan and auto-station data, deep learning etc. These methods have been used for short-time forecasting and nowcasting of thunderstorm, short duration heavy rain, thunderstorm wind and hail. These techniques have improved and promoted the short-time forecasting and nowcasting of the severe convective weather to some extent. The application of these technologies to aviation meteorological service will meet the urgent need of aviation weather for the short-time forecasting and nowcasting of the severe convective weather. The application of the above method shows good results to some extent. These technologies have a significant role to play in decision-making, whether for the weather forecasters at the airport or for the airport's controllers. It also improves the level and accuracy of the short-time forecasting and nowcasting for severe convective weather to a certain extent.





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### 1.2 – Wider Terminal Area

#### 1.2.1 – Significant convection research

### Nowcasting thunderstorms for aeronautical end-users.

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Speaker: Jean-Marc Moisselin  
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Thunderstorms are one of the most hazardous conditions for air navigation and aeronautical operations. Indeed, those meteorological systems can produce severe turbulence, low level wind shear, icing, low ceilings and visibilities, hail and lightning.

In addition to forecasters' assistance, Météo-France's nowcasting department is developing automatic tools for thunderstorm's detection and forecast among the first hours. Those products are designed for aeronautical use and aim at giving relevant information to pilots or air-traffic controllers to anticipate and circumvent such phenomena and optimise their flight paths.

In this presentation, we will give an overview of 2 systems based on an object-oriented approach: RDT (Rapidly Developing Thunderstorms) and ASPOC-3D.

RDT software is developed in the framework of NWCSAF. RDT uses brightness temperatures of geostationary satellites and optional data as NWP or lightning. data RDT detects, tracks and extrapolates thunderstorms cells. RDT also characterizes observed systems with different attributes such as overshooting tops, cooling rate, top of thunderstorm, high altitude ice crystal risk, etc. In order to cover aviations need, RDT is now produced on globe by Météo-France with 5 satellites.

ASPOC-3D combines radar information and satellite informations to detect, track and extrapolate convective cells. This product is dedicated to air-traffic controllers over France and Overseas territories.

These two products are based on present weather analyses and extrapolation of already initiated phenomenons since convective storms are difficult to predict precisely by classical numerical models.

Extrapolation techniques can't create non-observed systems nor change their intensity or motion and have difficulties to take into account the orography. Therefore their predictions are much less reliable when exceeding 1 hour.

New non-hydrostatic and high resolution models are now able to simulate some mesoscale phenomenas. Moreover, the increasing capacity of the computing centres allows a real-time operation of these models. AROME-NWC, Météo-France nowcasting NWP model has been in operation since March 2016. AROME-NWC fields can remedy known defects of extrapolation techniques. Blending these very different data is challenge for the nowcasting department. The aim is to take the best of each method to have the most relevant information without break during the 0-3h forecast interval.

A first merged version between QPE extrapolation and numerical prediction of rainfall is produced since December 2016. A fusion of reflectivities will also be implemented by the end of 2017. The use of such fields to feed thunderstorm's nowcasting products as ASPOC-3D is a way to deliver nowcasting information beyond the first hour of forecast and to smooth the transition between extrapolation and NWP forecast.





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## Session 1 – Science underpinning meteorological observations, forecasts, advisories and warnings

### 1.2 – Wider Terminal Area

#### 1.2.1 – Significant convection research

### Tracking and prediction of convective cells based on lightning data.

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Speaker: Stephane Pedeboy  
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Severe storms exhibit a common pattern consisting in a rapid increase of the total lightning rate (i.e. Cloud-to-Ground and Cloud-to-Cloud flashes) few to tenths of minutes in advance to heavy precipitation, hail or tornado. This “lightning jump” is an interesting feature for now-casting weather applications since it can help predicting severe weather occurrence with a sufficient lead time in most cases [Williams et al, 1999; Murphy and Demetriades 2005; Schultz et al, 2009].

Several algorithms have been developed to monitor lightning rate trends and detect the onset of the lightning jump based on VFH lightning data [Gatlin and Goodman 2010]. Out of those algorithms, the “2&#963; configuration” has been statically validated on various thunderstorm types and is likely to be the most effective to use for operational usage [Schultz et al. 2014].

Météorage has designed and developed a cell identification method using the DBSCAN algorithm [Ester et al. 1996] to cluster lightning data. In this algorithm so called STORM (Severe Thunderstorm Observation and Report Method) every individual cell is then tracked and its characteristics (eg. position, direction of propagation, speed, area and number of flashes) are monitored all long the lifecycle. In addition, the analysis of the evolution of the total lightning flash rate by the “2&#963; configuration” lightning jump algorithm helps predicting severe weather occurrences and triggering warning messages. To assess the performance of the system, a dataset consisting in 248 hail reports collected in 2014 across France by the ANELFA, the national association for hail risk prevention [Dessens et al 2006], has been cross-correlated with severe cells computed by STORM. Preliminary results show a clear seasonal dependency since winter storms are less likely to be detected by STORM because they produce few lightning. However, the Probability of Detection increases up to 80% for severe hailstorms producing hailstones with a diameter equal to or greater than 2.5cm. In addition, the mean Warning Lead Time is found to be about 15 min and reach 18 min for severe thunderstorms. Those results are consistent with those from similar studies [Schultz et al. 2009] demonstrating the usage of VLF/LF lightning data are relevant for severe storms tracking and alerts.

The usage of reconstructed lightning cell data based on individual lightning flash location provides a synthetic way to represent thunderstorms, giving a clear view to end users even during complex episodes. In addition, several physical characteristics including the severity based on the lightning jump occurrence are made available and the prediction of the future trajectory and status of the cell. Because this data is complete and simple to understand it permits to build efficient software helping in sensitive operations that need rapid decision-making. Out of them, several applications like air traffic control, ground operations and flying.





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**1.2 – Wider Terminal Area**

**1.2.1 – Significant convection research**

## Towards quantitative lightning forecasts with convective-scale Numerical Weather Prediction systems.

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Speaker: Olivier Caumont

Current operational Numerical Weather Prediction (NWP) systems running at the convective scale (i.e., with a horizontal resolution on the order of 1-3 kilometres) are able to forecast severe weather with increased realism and accuracy. However, they do not predict lightning directly although quantitative lightning forecasts could be useful for end users like aviation, and could also be used to assess the quality of the NWP forecasts.

Furthermore, lightning observations are potentially useful to improve the initial states of convective-scale NWP systems (and hopefully subsequent forecasts) through a process known as ‘data assimilation’. This is all the more relevant since other severe-weather observations are scarce in areas such as seas and mountains, whilst the coverage and accuracy of lightning detection instruments keep improving. For example, optical sensors can now be mounted on geostationary platforms such as the Geostationary Lightning Imager (GLI) aboard FengYun-4 (FY-4), the Geostationary Lightning Mapper (GLM) aboard GOES-16, and the Lightning Imager (LI), which will be launched aboard Meteosat Third Generation (MTG) from 2021.

All these applications need tools that are referred to as ‘observation operators’, which enable the simulation of observations from NWP systems. A major obstacle to designing lightning observation operators lies in the complex relationship between the physics of lightning discharge and the meteorological quantities that are usually predicted by NWP models. Although some explicit lightning representations exist, they are still deemed too expensive for real-time applications. For operational purposes, proxies appear appealing choices but need to be calibrated and evaluated.

Here, we have used lightning observations measured by a Lightning Mapping Array (LMA) and operational AROME-WMED forecasts to calibrate and evaluate proxy-based flash rate observation operators. The LMA has been deployed in south-eastern France during the first HYdrological cycle in the Mediterranean EXperiment (HyMeX) programme special observing period. Lightning data have thus been recorded for more than two months in the fall of 2012. For the same period of time, the AROME-WMED model has been run at a horizontal resolution of 2.5 km. Among other physical parametrizations, its microphysical scheme predicts the contents of water vapour and five hydrometeor species (cloud water, rain water, pristine ice, snow, and graupel). Ten proxies, based on hydrometeor contents, vertical velocity, etc., have been selected from the literature. They have been calibrated and evaluated through a two-step statistical method that circumvents double-penalty issues (i.e., related to erroneous locations in predicted convective systems). The method also enables, for each considered proxy, the determination of the time integration of the lightning observations for which the derived flash rates optimally match the model counterparts.





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## Session 1 – Science underpinning meteorological observations, forecasts, advisories and warnings

### 1.3 – Aerodrome throughput

#### 1.3.1 – Wake vortex detection and prediction

## Frequent-output sub-kilometric NWP models supporting enhanced runway throughput and performance-based navigation.

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Speaker: Kai-kwong Hon  
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Rapid advances in high-performance computing technology and meteorological modelling capability have made within reach numerical weather prediction (NWP) at unprecedented spatial resolutions even under real-time, operational settings. One such example is the 200-m resolution Aviation Model (AVM) of the Hong Kong Observatory, which provides fine-scale short-term forecasts in support of aviation operations at the Hong Kong International Airport (HKIA), one of the busiest in the world.

Meanwhile, evolving ATM needs (e.g. under the Aviation System Block Upgrade, or ASBU, methodology) have led to new requirements for specialised meteorological forecasts for both the terminal area and beyond (e.g. under the concept of Meteorological Services for the Terminal Area, or MSTTA), placing additional challenges to aviation-specific NWP. With a view to enhancing air traffic efficiency by increased runway throughput, an eventual goal of the ASBU work package on Advanced Wake Turbulence Separation includes a proposed move towards full dynamic Weather Dependent Separation (WDS). In WDS, the wake turbulence separation minima, one of the major factors governing airport arrival rate, would be determined dynamically with explicit consideration of current and anticipated meteorological conditions. This requires, in addition to establishing validated wake turbulence risk models and the corresponding time-based pairwise separation matrix, reliable frequent-updating short-term forecasts of key meteorological parameters (e.g. crosswind and low-level turbulence intensity evolution at 1-minute intervals or below) governing the decay and transport of aircraft wake vortices. Conventional limited-area mesoscale NWP models are clearly incapable of meeting such anticipated technical demands.

Here the capability of HKO's AVM in reproducing detailed wind variations along the arrival/departure glide paths, as well as near-surface turbulence intensity in terms of the eddy dissipation rate (EDR), would be examined through comparison with HKIA LIDAR measurements at up to 1-minute frequencies. Additionally, the fine-resolution lower-tropospheric wind profile nowcasts near the terminal area would be capable of providing meteorological support to continuous climb/descent operations (CCO/CDO) and performance-based navigation (PBN) for improved flexibility and fuel efficiency, contributing to seamless 4-D trajectory-based forecasts in a SWIM (System-Wide Information Management) environment. It is expected that rapidly-cycled sub-kilometric NWP models with high data output frequency would be essential in supporting and integrating with the next-generation air navigation systems in fulfilment of ASBU and beyond.







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**1.3 – Aerodrome throughput**

**1.3.1 – Wake vortex detection and prediction**

## Onboard Wake–Vortex Prediction Systems Employing Various Meteorological Data Sources.

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Speaker: Stephan Körner

Wake vortices, generated by aircraft en-route, naturally descend towards lower flight levels. Due to the minimum vertical spacing the possibility for an aircraft at lower flight level to encounter wake turbulence seems small at first glance. However, 73 wake-turbulence incidents have been reported at upper flight levels between 2009 and 2012. Furthermore, in January a Challenger business jet experienced a severe wake encounter with several passengers injured and the aircraft being forced to perform an emergency landing. To reduce the risk of wake vortex encounters in-flight on-board wake vortex forecasts can predict the position and strength of vortices generated by aircraft in the vicinity.

In this work the accuracy of wake–vortex predictions of DLR’s wake encounter avoidance and advisory system (WEAA) is analyzed by means of data gathered from a flight test campaign in April 2014. The system is based on airborne data exchange between aircraft and allows pilots to avoid potentially dangerous wake–vortex encounters. As the vortex evolution is strongly controlled by atmospheric parameters, the acquisition of meteorological data is crucial for WEAA. The accuracy of the wake–vortex predictions is investigated, employing first the current automatic dependent surveillance (ADS-B) standard, which is then extended by additional meteorological data transmitted via telemetry, or data from numerical weather predictions.







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### 1.3 – Aerodrome throughput

#### 1.3.2 – Fog/low visibility research

## PARAFOG: a new decision support system for the airports to monitor and to predict radiation fog based on automatic LIDAR-ceilometer measurements.

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and Hugo De Backer

Speaker: Quentin Laffineur

Radiation fog is the most frequent cause of surface visibility below 1 km, and is one of the most common and persistent weather hazards encountered in aviation and to nearly all forms of surface transport. Forecasting radiation fog can be difficult, a number of approaches have been used to integrate the satellite data, numerical modeling and standard surface observations. These approaches lack generally the vertical and temporal resolution, representation of boundary layer and microphysical processes. They typically do not represent accurately the activation processes of fog droplets that depend on the chemical and physical properties of the aerosols.

The automatic LIDAR-ceilometer (ALC) primarily designed for cloud base height measurement which can be found in most airports, has greatly improved over the last years and now provides high-resolution profiles of backscatter in the boundary layer in near-real time. The backscatter profile may be influenced by atmospheric humidity especially during the preliminary stage of radiation fog formation when the hygroscopic aerosols see their size increase with their moisture content.

The monitoring of the hygroscopic growth process through the backscatter profile measured by ALC, could provide useful warning to forecasters, in support of their fog forecast, minutes to hours prior to formation of radiation fog. In this context, a forward stepwise screening algorithm (PARAFOG) was developed (Haeffelin et al., 2016) and intends for use as a new decision support system for radiation fog forecasting based on analysis of the backscatter profile. This development was initiated in the framework of TOPROF (COST-ACTION, <http://www.toprof.ima.cnr.it/>) activities between the Royal Meteorological Institute of Belgium (RMI) and the Site Instrumental de Recherche par Télédétection Atmosphérique (SIRTA, IPSL).

In this presentation, we will describe the methodology used in PARAFOG to derive pre-fog formation alerts and we will show a selection of several radiation fog events observed on different sites to illustrate the efficiency of PARAFOG to detect radiation fog events.

Citation: Haeffelin, M., Laffineur, Q., Bravo-Aranda, J.-A., Drouin, M.-A., Casquero-Vera, J.-A., Dupont, J.-C., and De Backer, H.: Radiation fog formation alerts using attenuated backscatter power from automatic lidars and ceilometers, Atmos. Meas. Tech., 9, 5347-5365, doi:10.5194/amt-9-5347-2016, 2016.





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**1.3 – Aerodrome throughput**

**1.3.2 – Fog/low visibility research**

## LANFEX: Understanding fog behaviour in a region of small hills.

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Speaker: Léo Ducongé  
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The LANSFEX (Local And Non-local Fog EXperiment) campaign is an attempt to improve our understanding of radiation fog formation through a combined field and numerical study. The field trial was deployed in the UK for 18 months using an extensive range of surface based equipment, including some novel measurements (e.g. dew measurement and thermal imaging). In a region of hills we instrumented flux towers in four adjacent valleys to observe the evolution of similar, but crucially different meteorological conditions at the different sites, and correlated these with the formation and evolution of fog which formed within the valley cold pools. The results presented show certain locations are more prone to fog, as expected, but that the overriding condition for in situ fog formation within the cold pool is that turbulence must remain below a certain threshold. The presence of orography does not appear to affect the value of this threshold. Some early modelling results are also presented which illustrate the importance of both vertical resolution and turbulence parametrization on the formation and evolution of fog in valley systems.





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**1.3.2 – Fog/low visibility research**

## Towards a three-dimensional prediction of fog on airports with the Météo-France operational forecast model AROME.

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Speaker : Alain Dabas

On going research at Météo-France aims at improving its capacity to forecast fog on airports. Until recently, fog forecast was based on the high vertical resolution, 1D model COBEL complemented by local observations. Recent simulations of fog episodes at Roissy-CDG airport have shown the large horizontal heterogeneity of fog on the platform, and the role of local circulations. It now appears that the improvement of the forecast performance requires a 3D model. A programme has thus started aimed at testing a state-of-the art, 3D, local, fog prediction model. The model will be based on the limited area operational forecast model AROME of Météo-France with enhanced vertical and horizontal resolutions, and improved parametrisations for surface exchanges, microphysics, deposition... It will be run in real time (or near real time) during a field campaign in the winter of 2019-2020, during which many research and operational observation systems will be deployed, including microwave radiometers, 95GHz cloud radars, surface stations... This large dataset of observations will allow the evaluation of the 3D model performance for fog prediction and the assessment of the impact of the various parametrisations weighed by their computation cost in order to define a future forecast system dedicated to airports. The availability of observations, in particular from new sensors like the 95GHz cloud radar, will enable the conduction of assimilation impact studies and future recommendations for improved dedicated observation airport networks. The presentation will first summarize the results of the recent research actions on fog physics and numerical weather prediction conducted at Météo-France, based on innovative observation systems (microwave radiometers, lidars, UAVs), improvement of physical processes understanding (deposition, microphysics) as well as and their parametrisations, and operational model developments (resolution required for fog predictions). Then the program above will be presented.





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**Session 1 – Science underpinning meteorological observations, forecasts, advisories and warnings**

**1.4 – Space weather research**

## Space weather observations, analyses and generation output data messages for aviation.

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Speaker: Vyacheslav Burov

Nowadays the centre operates and fulfils numerous functions such as space weather monitoring, collecting, working and handing out the data to both Russian and foreign customers, compiling and spreading various kinds of the space weather condition forecasts. The first regular space weather forecast is known to have been issued on June 07, 1974. Since then this kind of activity has been processed and issued permanently 7 days a week. The data received by the activities are sent out in the form of the textual issues, as coded telegrams, alerts, circulated messages and by the open access for real time space weather information via the bilingual site: [www.space-weather.ru](http://www.space-weather.ru), and [www.ipg.geospace.ru](http://www.ipg.geospace.ru).

On the base of our monitoring tools such as:

- low-orbital satellites (including «Meteor»)
- high-orbital satellites (including “Electro”)
- radiotomography net
- network of the GPS/GLONASS receiving stations
- network of the ground ionospheric stations
- onboard ionosondes
- network of magnetic observatories
- network of riometers
- network of solar observatories
- world data resources

we issue the short-term forecasts for parameters of ionosphere, for radio wave propagation, for characteristics of the magnetic activities, the information concerning the time of the beginning and the end of the space weather disturbances.

Besides , we produce our real-time, global, physics-based model used to assess radiation exposure to aircrews and passengers (CRAT). The model predicts the radiation dosage in the atmosphere caused by cosmic radiation.

In this technique are used:

particle trajectory geomagnetic cutoff rigidity code for calculating cosmic ray particles GCR and SEP which are transported through the magnetosphere, the Russian standard of the atmosphere model for calculating the atmosphere density, the original procedure (developed in the IAG) for calculating the secondary particles' fluxes and the radiation dose rate.

The comparison of our calculation results with the results of EPCARD technique (Germany) and NAIRAS technique (USA) shows that there are no significant variations among them.





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**Session 1 – Science underpinning meteorological observations, forecasts, advisories and warnings**

**1.4 – Space weather research**

## Space Weather Services for Aviation - Current Capabilities and Future Needs.

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Speaker: Robert Rutledge

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Space weather services for aviation are progressing within the International Civil Aviation Organization (ICAO), with a commencement of services likely in November of 2018. Space weather can impact radio communications, satellite-based navigation, and lead to increased radiation exposure on rare occasion. Solar radio bursts can also affect satellite-based navigation as well as air traffic control radar. All of these have the potential to significantly impact aviation operations, particularly during the rare but extreme. The initial space weather services will provide increased, impact-based situational awareness to the aviation community. While valuable, these services are still maturing and will not fully meet customer requirements with respect to desired lead time, skill, and specificity. This talk will explore this emerging service area, covering what can be done today as well as what they future may hold.





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**Session 1 – Science underpinning meteorological observations, forecasts, advisories and warnings**

**1.5 – Atmospheric aerosols, volcanic ash research**

## Improved aerosol forecasting during extreme events by data assimilation

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Speaker: Laaziz El Amraoui  
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Aerosols have an important role in the atmospheric system of our planet. They have a major impact on the terrestrial radiative balance, the climate system, air quality and civil aviation.

Desert dust or volcanic ash are important sources of aerosols in the troposphere and have a direct involvement in the tropospheric composition: Desert aerosols directly influence air quality while volcanic aerosols has a great impact on civil aviation. It is therefore important to better understand the evolution and long-range transport of these types of aerosols in order to assess their impact in the atmospheric system as well as in aviation safety.

In this study, we assess the capacity of assimilation of aerosol products from the lidar network of Météo-France to improve the three-dimensional concentration of aerosols during extreme events (desert aerosol transport or volcanic eruption ). We also propose to study quantitatively the shape of the plumes and their impacts on French territory. The validation of assimilated products in terms of concentration of aerosols and AOD will be done in comparison with independent observations.





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**Session 1 – Science underpinning meteorological observations, forecasts, advisories and warnings**

**1.5 – Atmospheric aerosols, volcanic ash research**

## Development of an ensemble-based volcanic ash dispersion model for operations at the Darwin VAAC.

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Speaker: Rodney Potts  
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Airborne volcanic ash presents a significant safety risk to aviation. International arrangements have been developed to mitigate this risk through the activities of the ICAO International Airways Volcano Watch program and operations at associated Volcanic Ash Advisory Centres. Following the Eyjafjallajökull eruption in 2010 there has been a need for more information on the spatial variation in ash concentration and the associated uncertainties to enable airlines to better manage operational risk. There are significant challenges with this objective.

The Australian Bureau of Meteorology operates the Darwin VAAC and there has been ongoing development to improve guidance. The improved spatial, temporal and spectral resolution of the new Japanese Himawari-8 satellite data has greatly improved the detection and tracking of volcanic ash. These data are processed with the Spectrally Enhanced Cloud Objects (SECO) algorithm developed by NOAA NESDIS to provide quantitative estimates of cloud parameters including cloud top and the mass load. Forecast guidance is provided using the HYSPLIT dispersion model, and there has been work to better represent the particle size distribution of ash and to improve the parameterisation for the particle fall speed. It has been shown that wet deposition processes can have a very significant impact on the dispersion of ash in the Maritime Continent region which is both volcanically and convectively active.

The potential benefit provided by ensemble-based probabilistic dispersion model guidance has been demonstrated and the Bureau has recently developed the Dispersion Ensemble Prediction System (DEPS). This application allows forecasters to initialize the ensemble run based on output from a NWP ensemble system plus several other deterministic NWP models with defined eruption source parameters, providing guidance on uncertainties in the dispersion of ash and the probability of exceeding defined thresholds for the mass load.

Work is also underway to integrate observations with the dispersion modelling, using inverse modelling techniques, to better represent the source term and further improve available guidance.

The presentation will describe the DEPS, present some results and associated uncertainties and discuss planned developments.







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**1.5 – Atmospheric aerosols, volcanic ash research**

## Modelling and data assimilation of hazardous volcanic ash plumes in the chemical-transport model MOCAGE.

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Speaker: Bojan Sic  
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Volcanic ash aerosols can be emitted in significant amounts by volcanic eruptions and once airborne they pose a serious threat to aircraft engines. Especially after the Eyjafjallajökull eruption, important efforts have been put in the improvements to the volcanic ash modelling. Our research deals with spatial and temporal improvements of volcanic ash aerosols in the chemical-transport model MOCAGE, the operational air-quality and fast-response model of Météo-France. The main uncertainty source in volcanic ash prediction is still the emission term. To improve the estimation of the ejected mass and the particle vertical size distribution we introduce the plume rise model FPLUME in MOCAGE, which also takes into account the effects of meteorological conditions and of important physical processes like wet aggregation, air and particle entrainment, sedimentation, etc. An important attention is also given to the estimation of the initial size distribution at the vent. Instead of prescribed distributions depending on the eruption type, we implement a semi-empirical parameterisation that estimates the distribution based on the plume height and magma viscosity. The comparison between the operational and the new configurations shows that differences in the source term produce important differences in extent and concentrations of the transported volcanic ash plumes. Also, the results confirm that uncertainties of the volcanic ash modelling are considerable. For that reason, for the further improvements, we explore the axis of combining models with available Earth observation data in means of data assimilation in the framework of the European project EUNADICS-AV. The project's goal is the monitoring and assessment system for the estimation and the forecasting of the hazardous events, like volcanic ash plumes, where the data assimilation plays an important role. We evaluate the impact of observations on the plume characteristics by assimilating lidar profiles (spaceborne and ground-based) and satellite aerosol optical depth measurements in MOCAGE. We show that combining the modelling and data assimilation efforts is the necessary strategy in order to adequately improve the forecasts of the volcanic plumes that can impact the aviation safety.





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**1.5 – Atmospheric aerosols, volcanic ash research**

## European ceilometer and lidar networks for aerosol profiling and aviation safety – the German contribution.

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Speaker: Werner Thomas

Nowadays ceilometers, e.g. the Vaisala CL51 and the Lufft CHM15K Nimbus, allow detecting aerosol layers in the atmosphere up to the tropopause region (Wiegner et al., 2014). Based on experience gained during the European COST action EG-CLIMET (ES0702) another two European consortia established in 2013 and continued the work on harmonizing national ceilometer networks with respect to routine operations, data exchange and data formats (E-PROFILE, see <http://www.eumetnet.eu/e-profile>) and harmonized aerosol profile retrievals (TO-PROF, COST ES1303, see <http://www.toprof.ima.cnr.it/>), actively supported by EARLINET, the European Aerosol Research Lidar Network. Such combined networks of ceilometers and advanced lidar systems have already shown their value for providing the four-dimensional aerosol distribution over larger areas (Pappalardo et al., 2014).

The Deutscher Wetterdienst (DWD) contributes to the European ceilometer network with its currently 102 CHM15K Nimbus instruments (as of July 2017), which are all connected to the Internet. The processing of aerosol properties is performed automatically and unsupervised. At the national level in Germany the ceilometers and three lidar instruments are the aerosol measurement backbone of DWD, especially in case of volcanic eruptions and/or strong (mostly) Saharan dust outbreaks. Together with sun photometer observations, in-situ aircraft measurements and model simulations based on ICON-ART (Rieger et al., 2015) these are the pillars of the national volcanic ash advisory system.

The instruments provide freely available quick looks of the attenuated backscatter coefficient which can be accessed through the ceilomap web site hosted by DWD under [www.dwd.de/ceilomap](http://www.dwd.de/ceilomap). Computation of this physical quantity requires calibration of the instruments (see e.g. Wiegner and Geiß (2012); O'Connor et al., 2004), which was jointly developed within TO-PROF mainly by DWD, MeteoSwiss, and the University of Reading/UK. Also firmware issues need to be analyzed and taken into account (see Mattis et al., 2017; Kotthaus et al., 2016).

Several Saharan dust episodes, biomass burning plumes from Canadian wild fires in 2013 and volcanic ash plumes (Eyjafjallajökull 2010, Etna 2014) were tracked and analyzed in recent years and results will be shown. Moreover, data from the network are routinely used to validate modelled aerosol distributions provided by the COPERNICUS Atmospheric Monitoring Service (CAMS).

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## Session 1 – Science underpinning meteorological observations, forecasts, advisories and warnings

### 1.6 – Observation, nowcast and forecast of future needs

#### 1.6.1 – Advances in observing methods and use of observations

## Automated Aircraft Observations: Their importance to Future Aviation Transportation Operations.

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Speaker: Ralph Petersen

Numerous studies have assessed the impact of AMDAR temperature and wind reports in local forecast offices and both regional and global NWP systems. The results show very positive impact on time scales from hours to days. They also establish that aircraft data are by far the most cost effective of all major observing systems. New results will be included quantifying the impact of newly acquired AMDAR reports in previously data sparse areas.

The full impact of the AMDAR observations as a supplement/enhancement/gap-filler for traditional rawinsonde data in Numerical Weather Prediction (NWP) models, as well as for local, short-range hazardous weather forecast applications, has in the past been limited by the lack of sufficient moisture measurements in the aircraft ascent/descent profiles. Specific humidity reports are now available from over 135 aircraft over the US using the WVSS laser-diode sensor, providing more than 1000 profiles throughout each day. These data are as accurate and representative as rawinsonde humidity measurements, if not more so. Examples will demonstrate how forecasters have used these higher-time-frequency reports in a variety of hazardous aviation applications.

Although the use of frequently observed moisture profiles can play a key role in subjective Nowcasting, the impacts on NWP models are much more readily quantified. Two different approaches were used to assess impact in two NWP different systems – a data denial test and an adjoint-based observation sensitivity test, neither of which required substantial Quality Control changes. Note that improving moisture analyses and forecasts in larger-scale models is essential to advancing other higher-resolution aviation forecast systems, in that they provide analysis background and boundary conditions for local area models.

Results show that over areas with ample observations, AMDAR+WVSS profile data have a larger influence than any other in-situ moisture observation, with the greatest positive impact warm-season humidity analyses and forecasts (including precipitation) in the first 12 hours, and extending beyond 48 hours. Impacts are noted throughout the troposphere, with AMDAR+WVSS data collected during ascent and descent having nearly equal importance. The availability of multiple moisture observations at locations more distant from rawinsonde launch sites appears to contribute to the analysis and forecast improvements. Detailed comparisons against independent precipitation analyses and GPS total-column precipitable water measurements show improvements using WVSS reports in both extreme events and less dramatic cases.

The benefits of including these types of observations in future Aviation Operations systems that require improved global wind, temperature, tropopause, turbulence and precipitation forecasts are far reaching and range from terminal forecasts to weather hazard avoidance. The potential to obtain these observations both in areas where the continuation of upper-air observing programs are under budgetary threat and in forecast situations where additional observations are needed to fill the time and space gaps between once- or twice-daily RAOB launches will also be discussed.





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**1.6 – Observation, nowcast and forecast of future needs**

**1.6.1 – Advances in observing methods and use of observations**

## Remote-Ground based observations Merging Method for Visibility and Cloud Ceiling Assessment During the Night Using Data-Mining Algorithms.

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Speaker : Driss Bari

The occurrence of adverse cloud ceiling and visibility conditions that restricted the flow of air traffic in major airport's terminals is one of the main causes of aircraft delays and is crucial for air traffic safety and economic issues. In this study, Data-mining methods are applied to ground-based observations and satellite data to develop automated algorithms for the diagnosis of visibility and low cloud ceiling, during the night, in areas where no local observations are available. To achieve this, a database of hourly records of satellite data and conventional meteorological parameters has been used. It covers the winter months from January 2014 to February 2017 for 16 meteorological synoptic stations in the north-western part of Morocco. Based on ensemble approach, the developed classification decision trees have been used for the separate detection of fog and low cloud ceiling using only satellite data while the regression decision trees have been used for estimating the visibility and low cloud ceiling using a combination of ground-based observations and remote ones. Results show that detection of both phenomena has percent correct and probability of detection above 70% with false alarm ratio below 30%. The performance evaluation of the continuous parameter's estimation indicates a mean absolute error of 675m (resp. 540 m) with a 0,96 (resp. 0,93) correlation and a root mean-square error of 1120m (resp. 1070m) for visibility (resp. low cloud ceiling).





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### 1.6 – Observation, nowcast and forecast of future needs

#### 1.6.1 – Advances in observing methods and use of observations

## Operational uses of satellite observations for aviation support: today and tomorrow.

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Speaker: Timothy Wagner  
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As many flights operate over oceans and sparsely populated or less developed land masses, there is a paucity of conventional meteorological observations throughout significant portions of commercial aviation flight paths, especially along less-travelled routes. For a significant fraction of all aircraft in the air at any given moment, satellites remain the primary source of information about atmospheric conditions along their routes. These data are crucial for many applications: wind and temperature observations help flight planners optimize routes, observations of turbulence and convection help airlines maintain safety and passenger comfort, and volcanic ash detection helps optimize avoidance procedures. Information from satellites also indirectly supports aviation as satellites are the largest source of data for assimilation into the global and regional Numerical Weather Prediction (NWP) models that are invaluable for daily flight operations. Improvements in the satellite algorithms that feed into these models can enhance forecasts further.

As the 2010s draw to a close, we are in the midst of a great leap forward for satellite meteorology. The meteorological community needs to translate these observational advances into improved support for the aviation sector. The latest generation of geostationary weather satellites, including GOES-16 from the United States, Himawari-8 from Japan, and the forthcoming third generation of Meteosat satellites, promises to bring significant enhancements that will benefit aviation efficiency and safety. Combined with the continued enhancement and use of high-vertical-resolution data from the International Polar Orbiting Satellite Networks, the greatly improved spatial, spectral, and temporal resolution of these new systems will enhance the utility of existing products and enable the creation of new ones – in ranges from minutes to hours to 1-2 days in advance. This presentation will offer a survey of the current state of satellite meteorology for aviation and illustrate how these new satellite systems will benefit the aviation community for years to come. It will include a wide variety of examples of new products from the US and Europe, as well as examples of how the higher resolution observations and derived products are improving the NWP forecasts important to the aviation community.





# WMO Aeronautical Meteorology Scientific Conference 2017

6 - 10 November 2017

Centre International de Conférences - Météo-France - Toulouse - France

**Session 1 – Science underpinning meteorological observations, forecasts, advisories and warnings**

**1.6 – Observation, nowcast and forecast of future needs**

**1.6.2 – Seamless nowcast and numerical weather prediction, probabilistic forecast and statistical methods**

## Utilising Radar and Satellite Based Nowcasting Tools for Aviation Purposes in South Africa.

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co-authors: Morne Gijben, Stephanie Landman, Bathobile Maseko

Speaker: Erik Becker

In an effort to improve nowcasting for aviation applications, the WMO has initiated a research and development project which started in 2015 – called AvRDP. High density airports in different parts of the world were selected to take part in the initial phase where nowcasting techniques will be investigated and tested by means of various case studies. OR Tambo International Airport (ORTIA) in Johannesburg, South Africa, is one of the participating airports in this project, where convective weather dominates. Different nowcasting techniques related to convection will be investigated at this airport.

The South African Weather Service (SAWS) operates a radar network of 14 radars with a Doppler radar (S-Band, 10cm wavelength) just 25km North of ORTIA that provides reflectivity and velocity information. Currently the Thunderstorm Identification Tracking and Nowcasting (TITAN) software is utilised to track and forecast the movement of thunderstorm activity. Radar reliability and sparseness in some regions– such as large parts of the African continent – have made satellite derived products very popular and useful. The Nowcasting Satellite Application Facility (based in Spain) has made various products like Rapidly Developing Thunderstorms (RDT) and Convective Rainfall Rate (CRR) available for the purpose of nowcasting and their software has been operational in South Africa since 2013.

In order to improve the nowcasting capabilities of SAWS the community version of SWIRLS (Short-range Warning of Intense Rainstorms in Localized Systems), or com-SWIRLS was obtained from the Hong Kong Observatory. The software produces a deterministic forecast using extrapolation techniques from radar and satellite data. The SAWS is also experimenting with additional nowcasting applications utilising high resolution Numerical Weather Prediction (NWP) models in an attempt to increase the forecasting lead time to beyond 2 hours. Model runs include a 300m resolution run from the Unified Model as well as 500m runs using WRFDA data assimilated runs. The aim is to ultimately produce a seamless forecast through blending of the extrapolated and NWP forecasts.

In order to support decision making at the airport a lightning proximity and convective impact products have been developed for the ORTIA aerodrome. The product utilises the current TITAN tracking information operational at SAWS and Cloud-to-Ground lightning observations detected by the SAWS Lightning Detection Network. The products make use of tables for easy interpretation of the forecast. More information and results will be presented during the conference.







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## Aviation Weather Hazards Nowcasting Based on Remote Temperature Sensing Data.

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Speaker: Mikhail Kanevsky  
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Enhancing the short-term forecasting system for the weather phenomena and conditions with the greatest impact on aviation operations represents an important endeavor for improvement of the air navigation meteorological support which contributes to the safe, efficient and regular aircraft flights. One way of developing nowcasting systems is to integrate the existing observation data and mesoscale high-resolution models for the tasks of airport forecasting to support air traffic control during take-off/approach and airport service operations. This report describes a nowcasting subsystem based on an automated remote temperature sensing and nowcasting complex using the microwave profiler (MTP-5). The complex ensures automated remote temperature observations in the boundary layer of the atmosphere, as well as provision and visualization of observation data up to 10 km on:

- air temperature;
  - anomalies of the diurnal temperature range (warm or cold advection);
  - temperature and potential temperature at standard pressure levels;
  - altitudes of typical isotherms;
  - value of the temperature gradient in the lower atmosphere (up to 100m);
  - inversion presence, type and characteristics (interceptive layers);
- and automatic calculations for forecasts of the current weather phenomena and conditions at the airport, such as:
- fog probability;
  - cloud ceiling;
  - probability of freezing precipitation and icing.

The complex has been in trial operation in Pulkovo Airport (Saint-Petersburg) since March 2017. An extended data provision range and temporary extrapolation of observation data are ensured through blending the results of measuring the temperature stratification in the surface layer with the data of numerical models. Implementing the blending technology provides an opportunity to reliably assess the altitudes of typical isotherms that can be effectively used to identify meteorological phenomena in radar observations. High-frequency temperature profile measurements ensure real-time monitoring and prediction of formation and destruction of inversions, their quantitative characteristics and determination of the type and dynamics of both radiation and advective inversions. Preliminary results of the complex' operation show that the implemented indication technology for fog-related events of variable intensity allows successfully solving the problem of short-range fog forecasting (with a justification of up to 98%). The technology is based on the integrated use of surface observation data (dew point deficit and wind speed) and a continuous high-resolution stream of data from MTP-5 (gradients 0-200m, 0-50m, 0-altitude of the interceptive layer). A high degree of accuracy of algorithms for short-term fog forecasting is supposed to be ensured by adapting the criterial parameters of the forecast on the all-season data set. Among the features implemented in the automated remote sensing and nowcasting complex is the position indication for possible icing areas. Reliable data on the surface layer stratification obtained from MTP-5 provide an accurate assessment of the possibility of aircraft icing which directly depends on the actual temperature profile. In addition, since abnormal icing of aircraft can be observed under conditions of freezing precipitation, a technology for predicting the phase state of precipitation based on data of the surface layer temperature stratification is tested within the framework of the trial operation of the complex. In particular, the analysis of MTP-5 observations (in particular, the freezing rain in Moscow on November 10, 2016) showed that there is a potential possibility of predicting the fine structure of surface inversions several hours beforehand which provides an adequate assessment of the probability of ice rains.







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The use of nowcasting technologies based on the atmospheric temperature sensing performed by MTP-5 will ensure better planning of operations of airport services in hazardous weather conditions and increase flight safety.





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## Operational nowcasting systems in the framework of the 4-D MeteoCube.

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co-authors: Nikolay Bocharnikov, Alexander Solonin

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Speaker: Tatiana Bazlova  
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Nowcasting systems give relevant information support to decision-makers and aviation forecasters at airports with high traffic and/or many cases of high impact weather events. Nowcasting systems of IRAM operate 24/7 within three years in two airports providing specific required data. One of the airports is Irkutsk airport, whose operations are significantly impacted by low visibility caused by fog. The nowcasting system MeteoExpert has been put into operation at the airport since 2014 to provide the Aviation Meteorological Center with 0-6 hour forecasts of weather conditions including fog and visibility. Developed for operational use, numerical model of the atmospheric boundary layer (ABL) runs with a 10-min update cycle, data input from aviation weather observation station (AWOS) and three high frequency observing additional stations at fogging sites in the vicinity of the airdrome. Another one is Pulkovo airport, where more detail information is required in order to ensure the effective maintenance in winter and to improve the airport capacity. The nowcasting system MeteoTrassa has been installed to provide the airdrome service with a vital data for runways maintenance. Particular emphasis is placed on the information on icing at the surface and precipitation onset. This information helps airdrome service to react to hazardous weather in time and to initiate preventive works. Measurements (including runway surface parameters) together with short-term forecasts of icing at the surface and precipitation are provided by the system. Measurements and forecasts are visualized on screens of workstations, intranet websites, and the MeteoCube website. The 4-D MeteoCube was designed at IRAM in accordance with the ASBU concept of the 4-D database of MET information as the best choice to ensure that accurate weather data would be integrated into operational decision making. The MeteoCube contains continuously updated weather observations (standard and non-standard data, such as data from road weather stations), high resolution forecast information (conventional data from numerical models), and observations and forecasts of parameters relevant to aviation (convection, ceiling and visibility, icing on runways). Results of forecast verification over three years are presented.





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### Probabilistic weather hazard forecast guidance for transoceanic flights based on merged global ensemble forecasts.

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Speaker: Matthias Steiner  
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The next generation of global aviation weather hazard forecast guidance will be probabilistic in nature and based on merging ensemble forecasts from multiple global weather prediction centers. This will satisfy the requirements set forth by ICAO and WMO in their Aviation Systems Block Upgrades (ASBUs).

A methodology was developed for calibrating and merging ensemble forecasts from multiple sources to create a globally-harmonized, gridded, probabilistic weather hazard forecast guidance for strategic use in planning of transoceanic flights. At present, the methodology is exercised in a real-time prototype using a North-American combination of ensemble forecasts produced by the United States (GEFS) and Canada (CMCE) with a focus on convective storm hazards, although the approach is applicable to other aviation weather hazards as well. The assessment is based on a global precipitation product (CMORPH). The presentation will discuss the methodology and results from offline studies that evaluated various aspects of the merging and calibration, including tradeoffs between combinations of ensemble forecasts from the United States, Canada, United Kingdom, and the European Centre for Medium-Range Weather Forecasts.

Looking ahead, the ever-increasing spatial and temporal resolution in numerical weather forecasts will benefit future prediction of global aviation weather hazards, as the relevant atmospheric processes get better resolved and the operational models evolve towards meso-scale ensemble forecast systems covering the globe. Remaining challenges include the difficulty of defining an aviation weather hazard truth (what should be avoided for a variety of reasons) and collection of relevant data for forecast assessment and calibration; tradeoffs between forecast reliability, resolution and sharpness; ensemble size and scalability; and issues with bandwidth for distribution of data.

Disclaimer: This research is in response to requirements and funding by the Federal Aviation Administration (FAA). The views expressed are those of the authors and do not necessarily represent the official policy or position of the FAA.





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### 1.6 – Observation, nowcast and forecast of future needs

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### Applying Statistical Tool CLIPER for Forecasting Visibility at Airports.

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Speaker: Jadran Jurkovic  
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One of the biggest challenges in meteorology is predicting fog. Aviation meteorology has a special interest in visibility forecasts at airports since low visibility and ceiling conditions can cause many troubles to the traffic at airports and along routes. Theoretical background of processes in fog is well understood and availability of the measured data at airports is very good. But forecasting of fog at one site, such as airport, is difficult. Moreover, for example in Terminal Aerodrome Forecast (TAF), it is very hard to meet required visibility criteria stated in ICAO Annex 3.

Usually, several approaches are used to forecast visibility operationally. Usage of models, post processing and statistical tools (or combination of them) are the most common ones. In Croatia Control we implemented CLIPER - simple statistical model for probabilistic short-range forecasting (nowcasting) proposed by Juras and Pasarić in 2006. Actual visibility is related to climatological visibility distribution for the present hour and month. The corresponding percentile of the visibility, in its equivalent normal distribution, is in the following hours slightly moved from starting percentile to the median, depending on strength of the correlation coefficient between hours. Forecast of visibility is given for the following 9 hours. This method should be helpful tool to the operational forecasters in forecasting especially low visibility. It is rather easy to apply it to all airports with METAR databases.

In Croatia Control, operational forecasters use so called 'fog panel' that consists of several graphs which show present and recent measured visibility and climatological distribution. In addition to the median forecast of visibility (which is basically the 50th percentile), 50 % and 80 % confidence intervals are shown as well to provide a measure of the forecast uncertainty. Verification of results for last cold season at Zagreb Airport shows very good result in anticyclonic situation and especially for fog dissipation. Together with the observations and NWP models, this statistical method complements the visibility nowcasting methods.





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## 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  
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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 coordinate 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.





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## 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.

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Speaker: Florent Birling  
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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 crystals 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 world-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](http://www.ewas.aero).





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## 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.

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co-author: A. Mermet

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Speaker: Axel Piroth  
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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.







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## 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  
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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.





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## 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  
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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.





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## 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 Management.

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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>





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**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.





# WMO Aeronautical Meteorology Scientific Conference 2017

6 - 10 November 2017

Centre International de Conférences - Météo-France - Toulouse - France

**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.





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

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Speaker: Svenja Koos

The SESAR Deployment 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.







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## 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.





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## **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  
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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.





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#### COLLABORATIVE DECISION 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 "AERGRAMME". 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 !"





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

PW Peter LI, Hong Kong Observatory, Hong Kong, China  
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Speaker: PW Peter LI  
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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.





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

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Speaker : Pauline Jaunet  
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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 occurred 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.





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## The Remote Oceanic Meteorology Information Operational (ROMIO) Demonstration.

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Speaker: Eldridge Frazier

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.







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#### Integrated Wind and Turbulence Forecasts for Automated Flight Route Planning.

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co-authors: M. Strahan, R. D. Sharman

Speaker: Jung-Hoon Kim

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 Angeles 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.







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## Flight Execution and Route Adaptation Considering Multiple Weather Hazards.

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Speaker: Manuela Sauer  
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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.





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## 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.





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

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Speaker: Jos de Laat  
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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.





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

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Speaker: Philippe Arbogast  
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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.





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

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co-authors: V.r Grewe, ATM4E Project Team

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 CO<sub>2</sub> and non-CO<sub>2</sub> 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.





# WMO Aeronautical Meteorology Scientific Conference 2017

6 - 10 November 2017

Centre International de Conférences - Météo-France - Toulouse - France

## Session 3 – Impacts of climate change and variability on aviation operations and associated science requirements

### 3.1 – Jet stream position and intensity and related phenomena

#### Global Response of Clear-Air Turbulence to Climate Change.

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Speaker: Paul Williams  
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Clear-air turbulence (CAT) is one of the largest causes of weather-related aviation incidents. Anthropogenic climate change is expected to strengthen the vertical wind shears at aircraft cruising altitudes within the atmospheric jet streams. Such a strengthening would increase the prevalence of the shear instabilities that generate CAT. Here we use climate model simulations to study the impact that climate change could have on global CAT by the period 2050-2080. We analyze eight geographic regions, two flight levels, five turbulence strength categories, and four seasons. To estimate the uncertainties in our projections, we use two different climate models and we calculate 20 different CAT diagnostics, each converted into eddy dissipation rates.

We find large relative increases in CAT, especially in the mid-latitudes in both hemispheres, with some regions experiencing several hundred per cent more turbulence. The busiest international airspace experiences the largest increases, with the volume of severe CAT approximately doubling over North America, the North Pacific, and Europe. Over the North Atlantic, severe CAT in future becomes as common as moderate CAT historically. These results highlight the increasing need to improve operational CAT forecasts and to use them effectively in flight planning, to limit discomfort and injuries among passengers and crew.





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## Session 3 – Impacts of climate change and variability on aviation operations and associated science requirements

### 3.1 – Jet stream position and intensity and related phenomena

#### Aircraft observations and reanalysis depictions of trends in the North Atlantic polar front jet stream wind speeds and turbulence.

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Speaker: Joel Tenenbaum  
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Multiple model-based studies of the North Atlantic polar front jet stream have considered the effects of doubled CO<sub>2</sub>. Two key questions are whether any effects can already be seen and whether any effects can be seen independent of computer models. A major tool in the climate change community is atmospheric reanalyses which calculate an optimum depiction of the jet stream when the reanalysis model is held fixed for 50 to 100 years. But such reanalyses do depend on the underlying assimilation model. In addition, any secular trends must be disentangled from other oscillations that affect the North Atlantic: the North Atlantic Oscillation (NAO) and the Atlantic Multidecadal Oscillation (AMO).

We have addressed these issues by using three separate sources: the NCEP/NCAR reanalyses, the underlying AMDAR/ACARS aircraft wind observation archive, and the Global Aircraft Data Set (GADS) archive. The reanalyses are somewhat correlated with AMDAR because those observations form a major component of cruise-level results. The 3 billion GADS observations (100 million over the North Atlantic during 2002-2017) taken from the flight data recorders of multiple carriers are independent of both reanalyses and AMDAR. They also provide direct measurements of the turbulence associated with the North Atlantic jet.

One result yields a small increase in the jet stream wind speeds over the period winter (DJF) 1979-2017. But that increase is not statistically significant and is possibly due to the flip in the strength of the AMO around 2000. When we eliminate the effects of the AMO by concentrating on 2002-2017, a second result shows increases in wind speed which are statistically significant at the 10% level. Their geographical distribution is consistent with the modeling results of 21st century doubled CO<sub>2</sub> of Delcambre et al. who suggest a decrease in the Atlantic jet core and an increase in the jet exit regions. The GADS results also show wind speed increases but are only currently processed for 2002-2013. There is no clear trend in "light" turbulence. Our results are consistent with the predicted increase of the jet stream speed but too short to definitively prove the case at this time.







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## Session 3 – Impacts of climate change and variability on aviation operations and associated science requirements

### 3.1 – Jet stream position and intensity and related phenomena

#### Impact of Large-Scale Climate Variability to Long-Haul Flight Routes and Clear-Air Turbulence.

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Speaker: Jung-Hoon Kim  
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Mid-latitude jet streams have seasonal and inter-annual variabilities in strength and position, which are correlated with large-scale climate variabilities like the North-Atlantic Oscillation (NAO) and El-Nino Southern Oscillation (ENSO). Near the jet stream, Clear-Air Turbulence (CAT) frequently occurs, mainly due to the shear instability. For safe and efficient strategic flight planning, it is beneficial to study the impact of large-scale climate variability on flight planning and CAT.

Wind-Optimal Route (WOR) is calculated using the global reanalysis data with  $0.5 \times 0.5$  degree of horizontal grid spacing, which considers wind variations in the flight trajectory modeling to minimize total flight time between two city points anywhere in the world. Then, overall flight times and potential CAT encounters from turbulence along the simulated routes are calculated using the longer-term reanalysis data. We conducted two experiments. The EXP1 is for a city pair between John F. Kennedy International Airport (JFK) in New York and Heathrow Airport (LHR) in London during the wintertime of extremely positive (2004-05) and negative (2009-10) NAO periods to see the impact of NAO pattern to flight route and CAT. Another (EXP2) is for a city pair between Hawaii and western coast of US during extremely positive (1997-98) and negative (1998-99) ENSO periods.

In EXP1, the Eastbound (EB) WORs from JFK to LHR are shifted northward to take advantage of the strong tail winds (to reduce total flight time/fuel used), while Westbound (WB) WORs from LHR to JFK disperse to avoid the strong head winds near the jet stream during the positive NAO phase (2004-05) period. On the other hand, in negative NAO phase (2009-10), the EB WORs shift southward to take an advantage of southerly shifted jet stream, while the WB WORs are close to Great Circle routes (shortest distance) due to an absence of strong head winds. Turbulence encounters along the WORs are higher in EB than WB, because EB generally flies close to the strong jet stream to benefit from the tail winds.

In EXP2, EB WORs from Hawaii to the West coast are shorter and faster in positive ENSO period than those in negative ENSO period, because + ENSO modulates the mid-latitude Pacific jet to be elongated to further East. Turbulence potentials are higher in + ENSO than – ENSO period. This suggests a good relationship between the large-scale climate weather patterns and optimal (i.e., minimum fuel used and minimum chance of turbulence encounters) long-haul flight routes, which can be useful for long-term strategic planning for aviation.





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## Session 3 – Impacts of climate change and variability on aviation operations and associated science requirements

### 3.2 – Extreme weather events at airports, changes to established scenarios

#### Climate change aspects of fog/smog occurrences at different low visibility ranges in Delhi Airport: Temporal change using general visibility 1964-2017 and Spatial changes within airport during 1989-2017 using multi-RVR data and linking them trends of Met parameters (RH, Temp, Wind).

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Speaker: Rajendra Kumar Jenamani  
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Climate change aspects of fog/smog occurrences at different low visibility ranges in Delhi Airport: Temporal change using general visibility 1964-2017 and Spatial changes within airport during 1989-2017 using multi-RVR data and linking them trends of Met parameters (RH, Temp, Wind).

Delhi IGI Airport operational since 1950s have undergone vast changes over the period both in aviation infrastructure and so also shift in its winter smog/fog occurrences as it was believed in 1950s there were some days when vis above 5000m were available for flight landing even in peak winter of Dec-Jan in contrast to even late 1990s for same period when visibility never cross 2000m due to increase of urbanizations and traffic surrounds to it. With new RWY built and operational by Aug 2008 located at far southwest corner and at rural side and on land area, where it was all open and more water body and greenery, fog being very much sensitive to local features, a high different in duration intensity of fog, we start noted when total CAT-IIIB fog duration are compared from their corresponding six number of RVR at respective RWY ends. It finds new RWY 29-11 side are very higher in total duration in a season compared to main old RWY 28-10 located at city side at more northeast of it having more urbanized one in terms of big highway lies very closed to its RWY 28 TDZ end and hence with time all aviators start naming the latter RWY as life line of IGIA, as it facilitates last flight to land in low visibility and such, this TDZ sometime closed after 4-6 hours of that TWY29 TDZ and RWY 11 TDZ during dense fog events even upto CAT-IIIB dense fog which is very unique spatial pattern fog variability and creates a complex scenario for ATM/Airport management. In the present study, Climate change aspects of fog/smog occurrences at different low visibility ranges in Delhi Airport using very longer period data at hour to 30-minute intervals of daily data for months of peak winters of Dec-Jan have been attempted. We have studied Temporal change using general visibility 1964-2017 and Spatial changes within airport during 1989-2017 using multi-RVR data. Frequencies and duration of fog/smog at Delhi at <1500, <800m, <400 and <200m since 1960s till 2015s in 5-years means when performed, it finds both geeral and dense fog duration have increased by 30-40 and 15 times respectively which has been quite alarming for aviation operation. Within the airport, there are stronger climate change signature at meso- scale upto 3-6km scale too, fog being very sensitive to local features variation as RVR studies using meso-network of RVR data finds dense fog occurrences at new RWY 29-11 which was 1.5 time to old city side RWY 28-10, in start of its operation in 2008-09, has increased to 4-5 times in recent seasons of 2015-17. We have linked such variation with fog formation parameters e.g winds, temp, RH, pollutants acting as CCN for same period which also interestingly concluding significant increasing of moisture, fall of max temp by 2-3degc and weakening of airport surface winds and high increase of favorable pollutants.





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## Session 3 – Impacts of climate change and variability on aviation operations and associated science requirements

### 3.2 – Extreme weather events at airports, changes to established scenarios

#### On variation of several climatological characteristics at aerodromes in the Russian Federation in 2001-2015.

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Speaker: Anna Ivanova  
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Variation for several aeronautical climatologically characteristics were studied on the basis of hourly (half-hourly) meteorological terminal observations at 51 aerodromes of the Russian Federation in 2001-2015. For every aerodrome extreme temperature, wind and gusts, QNH were analyzed. Using data of three consecutive 5-year periods the variation of number of days with temperature values below -30 Celsius (very cold) degrees and above 30 Celsius degrees (hot), wind speed more than 10 ms-1, gusts more than 15 ms-1 were considered. Occurrence frequency of significant weather effecting on takeoff and landing (fog, blizzard, freezing precipitation, thunderstorm) is explored. Results for aerodromes with positive or negative trends of occurrence frequency of weather phenomena in 2001-2015 are exhibited.

Such trends occur at ~25-40% aerodromes, more often – located in European part of Russia. Between 2001-2015 a decrease of hot days at some aerodromes as well as an increase of very cold days at others were detected. The change of wind conditions at Russian aerodromes is characterized by heterogeneity. As for significant weather for landing, take-off, and terminal services operations (apart from thunderstorms), one can observe negative trends in its occurrence frequency, especially in the European part of Russia.

Many aerodromes are characterized by multiple climatic variations. So, at the Moscow aerodrome Domodedovo occurrence frequency of thunderstorm increased, the same occurrence frequencies of fogs, blizzard and freezing precipitation decreased.





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**Session 3 – Impacts of climate change and variability on aviation operations and associated science requirements**

**3.4 – Re-evaluation of airframe/avionics resilience standards and certification**

## The Aircraft Flight Envelope.

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Speaker: Rainer von Wrede  
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How does climate change influence aircraft design and operation?

Aircraft are designed to operate within a given range of static temperatures and altitudes (pressures), called the aircraft flight envelope. Aircraft manufacturers strive to extend this range to the maximum to give airlines the highest operational flexibility. Although flight envelopes are of similar shape, they are specific for every aircraft type and are determined by airworthiness certification. An aircraft is not allowed to operate in atmospheric conditions which are outside the certified flight envelope. Increasing or decreasing temperatures can then e.g. prevent airlines to reach certain airports occasionally, or even permanently. The dynamic behaviour of the atmosphere is potentially also altered by climate change, and may further impact aircraft design and/or the operations.

Aircraft manufacturers therefore need to know the impact of climate change on the flight envelope and the dynamic properties of the atmosphere to adapt the design accordingly. This presentation aims at describing the limiting design aspects of a typical aircraft flight envelope.

