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

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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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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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 ΦDP and half its range derivative specific differential phase KDP, as well as the copolar correlation coefficient RhoHV. 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°C to -8°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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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/m3) 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/m3. However, the large majority of these detections still contain IWC values between 0.1-1 g/m3. 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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1.1.2 – 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 Parater (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 oragraphy, convection and horizontal wind shear. Cases with turbulence incidents will be considered to examplify theses different sources in practice. In addition we present first results of a one year verification against commercial air-craft measurements.

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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.

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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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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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Nowcasting thunderstorms for aeronautical end-users.

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Speaker: Jean-Marc Moisselin

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, Meteo-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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Tracking and prediction of convective cells based on a lightning data.

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Speaker: Stephane Pedeboy

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 “2σ 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 “2σ 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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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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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

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 MSTA), 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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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.

Session 1 – Science underpinning meteorological observations, forecasts, advisories and warnings
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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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 hydroscopic aerosols see their size increase with their moisture content.
The monitoring of the hydroscopic 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.imaa.cnr.it/) activities between the Royal Meteorological Institute of Belgium (RMI) and the Site Instrumental de Recherche par Télédéction 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.

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

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

The LANFEX (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.

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

1.3 – Aerodrome throughput

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 aimes 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.

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, and 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.

***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.

Robert Rutledge, NOAA Space Weather Prediction Center, United States of America
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Speaker: Robert Rutledge

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.

***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

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.

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

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.

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

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

Volcanic ash aerosols can be emitted in significant amounts by volcanic eruptions and once airborne they pose a serious treat to aircraft engines. Especially after the Eyjafjallajokull 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.

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

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.imaa.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. 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.

***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

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).

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

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

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Speaker: Timothy Wagner

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.

***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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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 obtain 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 develop 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.

***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

Aviation Weather Hazards Nowcasting Based on Remote Temperature Sensing Data.

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Speaker: Mikhail Kanevsky

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.

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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1.6 – Observation, nowcast and forecast of future needs

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

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

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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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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.

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Applying Statistical Tool CLIPER for Forecasting Visibility at Airports.

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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 Pasaric 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.