The bridge from meteorological research to improved safety of air transport

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Meteorology as a research field is fragmented into specialized fields, and while all research ultimately supports the overall objective of better serving society and customers, the needs and requirements of the air transport sector require special attention due to the unique impact weather has on the operations in the sky and the specific phenomena affecting aircraft, airports and ATM. The human intervention in aviation weather forecasting is one of the strongest bastions of the forecasters’ skill to improve the forecast skill, but automation and technology improve both the guidance received by the forecaster and the actual end products automatically generated by various processing methods.

In its end-year report IATA (2016) estimated that 0.9% of world GDP, totalling $769 billion, is spent on air transport in 2017, providing employment to some 2.67 million and contributing to 2.5% of world GDP growth. Prospects for growth for airlines in the United States seem especially promising. The total weather service market in US is estimated by AMS (2012) to be worth around $4-5bn, of which $1.65 to 1.8 billion were attributed to the private sector (Spiegler 2007). Out of the private sector weather service costs, an estimated 5% ($82.5 to $90m) were related to aviation.

Figure 1: Estimation of global aeronautical meteorological service provision cost as a fraction of the total air transport cost

The total share of aeronautical meteorological (MET) costs on air transport costs range widely from country to country. Aeronautical meteorological costs are typically included in Air
Navigation Service (ANS) costs when charged from the user. The share of MET cost of total ANS costs in Europe as estimated by Eurocontrol (2004) for 2002 was 6.7% (decreasing from 7.9% in 1998). European air transport operators paid in total €380 million for MET services in Europe in 2002.

The lack of consistency on cost recovery policies for MET services makes comparison difficult and distorts the overall picture, but a rough estimate of 5-10% of Air Navigation Service charges globally can be applied for MET services according to the available published literature. Global ATM costs are estimated at $10.9 billion in a report by Eurocontrol (2016) and total ATM & ANS costs roughly $50bn (6.5%) of total air transport costs. Assuming an average 7.5% MET share of the total ATM/ANS, we could estimate that roughly $3.7 billion is allocated annually to support MET service provision, excluding any government funding or military spending (see Figure 1). Since 2002, significant cost pressure has been imposed on the global meteorological community via various instruments while cost of infrastructure has increased.

**Improving Terminal Manoeuvring Area wind forecast accuracy**

![Figure 2: Schematic representation of the required steps leading to improved TMA wind service for aviation. Meteorological components indicated in brown and added value in dark red background colour.](image)

Wind speed and direction between surface and 3000ft (1km) is typically critical in the selection of the used runway configuration which in turn directly affects the capacity of the airport. While current numerical weather models generally perform quite well in wind forecasts, airports situated near e.g. orographic features or large bodies of water (or both) are still difficult to forecast accurately. Improvements in the four-dimensional field of wind speed and direction have the potential to improve the capacity management of an airport.

The expected positive impact on the operations of the airport will result from the optimal use of the provided decision support by the human operators. The underlying assumption is that...
the improved wind field will result in more temporally accurate, and thus efficient, runway configurations as demonstrated by e.g. Météo-France using a 100m grid resolution for Paris CDG airport. Restrictions could actually increase as a result, but this would lead to reduced holdovers for incoming air traffic and hence reduced fuel burn and arrival delay. The optimal situation for all concerned entities is for the aircraft and passengers to be able to complete the flight with minimal disruptions and for the additional wait to happen at the terminal.

**Impact of improved turbulence guidance for airspace users**

Airline company policies dictate as to what information is given to the pilot and hence this step is under the responsibility of the airline. Demonstrations of such service provision to e.g. Lufthansa pilots for trans-Atlantic flights exist with results. A company promise to customers and crew members for a smoother and safer flight should be a substantial competitive advantage not yet seized by many of world’s leading airlines.

![Figure 3: Schematic representation of the required steps leading to improved in-flight turbulence service for aviation.](image)

**Enhanced liquid water equivalent forecast to de-icing operations**

Measurement history will provide the baseline for future development of meteorological algorithms to support de-icing operations. This baseline should then be used to enhance the parameterisation and representation of liquid water equivalent (LWE) which is a useful proxy for de-icing need for an airframe both in the nowcasting timeframe and medium-range planning. A statistical approach using a history of de-icing fluid use and de-icing need will help in calibrating the forecast accurately to previous incidents, will improve accuracy and reduce bias. The past realised de-icing operation data requires for good cooperation with the ground handling companies and such a project in general can only be realised in close collaboration.
from the start. With the observation and de-icing climatology available, the forecast method can be tailored for the airport in question with the required accuracy. The actual forecasts should then be verified against true de-icing operations at the airport in question to ensure of the usability of the product. A successful project will result in an all-round more efficient de-icing process and less take-off delay for the passengers.

**Figure 4:** Schematic representation of the required steps leading to improved de-icing and anti-icing service for aviation.

**Detailed no-fly zones for rotorcraft and RPAS operators**
Both helicopters and RPAS manufacturers publish tolerances for meteorological conditions and these can be combined with the pilots’ guidelines on safe flight and operator policies to create meteorological operating constraints specific to the aircraft and operator. SIGMET is the closest equivalent of a product needed for RPAS operators. SIGMET could be altered in a way to be adaptive to the aircraft type or use the strictest rules for small RPAS. However, the product should not be in the traditional alphanumeric format since this would be illegible to most operators but rather be a visual product in line with a Significant weather chart. Such a chart could include permanently restricted areas for RPAS flight and be automatically generated. Most RPAS manufacturers include the ability for geofencing their equipment via hardware configurations to inhibit their flight into restricted airspace. Ideally, such technology could be used to generate a weather-geofence to inhibit flight into areas of significant weather determined by international standards.
Figure 5: Schematic representation of the required steps leading to no-fly zones for rotorcraft and RPAS operators.

Weather constraints translated to effective decision support products for Air Traffic Management

Figure 6: Schematic representation of the required steps leading to improved consideration of weather impacts on air traffic management.

In ATM support efforts, the exact quantification of impacts by weather becomes a key priority. The mitigation strategies need to also be very clearly defined when an algorithm is deployed to provide decision support, i.e. the process of what is the optimal runway configuration with 25kt wind from the East and what capacity effect it has or how much capacity is reduced when
visibility is below 1000/3000/5000ft should be clearly known when developing support systems. Accurate meteorological information in collaboration with other information sources should lead to improved situational awareness at airport and airspace management level and hence result in better utilization of airport and airspace capacity leading to less delays for airlines and passengers.

**Super high resolution numerical weather prediction models for airport domains**

Research and development of especially temporally higher resolution nowcasting models could be carried out as an international or regional collaboration to reduce the cost and duration of such a project. Projects should also be based on existing solid research findings to justify the selected approach. Particular importance should be given to the verification of operational model output against limited area and global models in aviation-specific cases to demonstrate suitability for aviation purposes. Any post-processed output should also be carefully evaluated and verified against operational aviation weather observations to ensure the quality and consistency of the produced information. Extensive post-processing should be avoided since it will make the ongoing development of the model more difficult as the methods must be also updated and output verified following each update.

**Figure 7:** Schematic representation of the required steps leading to improved temporal and spatial resolution in numerical weather models used for aviation weather forecasting.

**Improving forecasts of High Ice Water Content concentrations**

From a meteorological standpoint, the research challenge is on the correct identification of deep convection leading to overshooting tops capable of producing ice crystals at high altitudes from available remote sensing information and the subsequent nowcasting and forecasting of the evolution of the systems. Ground-breaking work has been achieved in the High Altitude Ice Crystal (HAIC) research project¹ led by Airbus in collaboration with several meteorological service providers and industry to better understand the phenomena and develop nowcasting

¹ [http://www.haic.eu/](http://www.haic.eu/)
capabilities and from a 2014 field campaign in Darwin, Australia by NCAR. The methods developed and deployed to identify severe turbulence areas from weather satellite data are essentially what can be used to also identify areas where ice crystal concentrations are likely to be high. Since the provision of global significant weather charts currently lies with World Area Forecast Centres, and to ensure global consistency and interoperability, warning on ice crystal concentrations could be assigned to the WAFCs.

Figure 8: Schematic representation of the required steps leading to improved forecast and warning of high altitude ice crystal risk.

Harmonisation and collaboration between MET service providers
A global strategy and roadmap to encompass meteorological service provision can be only founded on the defined needs and requirements of the main air transport industries. A high-level dialogue needs to take place where the airline and ATM representatives form a definitive roadmap together with the meteorological service providers based on the existing service capability, trends in the air transport industry and technological developments.

The objectives and visions should to be translated into a global action plan and strategy following the detailed definition of end user needs and requirements. This development should be co-led by ICAO and WMO and should build on the existing Global Air Navigation Plan (GANP) and ASBU methodology. Currently the focus of these Block Upgrades has been almost solely on the World Area Forecast System (WAFS) development and the SWIM architecture without any clear guidance as to where the entire community of meteorological service providers should focus their development in order to improve aviation safety. The global vision needs to include a position on what the most important research questions are and where the integration of meteorological information to decision support systems is most needed.
Figure 9: Schematic representation of the required steps leading to improved global meteorological service provision.

The monitoring of performance needs to be streamlined and user focused at a regional level. This could be achieved by holding annual stakeholder review meetings where regional total meteorological service costs are presented and discussed and user feedback received on the most important investments at a regional level. A global stakeholder workshop between ICAO, WMO, IATA and CANSO with regional representation should complement the regional level to provide a global consensus on the meteorological service cost and future investments into research and development. Transparency into planned and ongoing development activities with open access publishing standards of research results of meteorological applications will speed up development significantly. When considering the global, regional and local level mechanisms for funding research and development actions, open sharing of research results should be a key priority.

References: