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# REVIEW OF DATA REQUIREMENTS FOR AERONAUTICAL METEOROLOGY


*(Submitted by Dr Herbert Pümpel,*

*Co-Chair of the TREND OPAG, CAeM)*



**Summary and Purpose of Document**

This document reviews the requirements for observational data to fulfil the goals defined in its 5th Long-term Plan.


**ACTION PROPOSED**

The meeting is invited to consider and discuss the views presented in this document.

## OVERVIEW OVER RECENT DEVELOPMENTS IN AVIATION OPERATIONS

1. A series of events have accentuated the underlying structural problems in the aviation industry globally from the aftermath of 9/11 to SARS the economical basis of many airlines have become critically eroded and the industry is increasing its pressure on ancillary service providers to reduce costs while looking for improved ways of operating at lower cost. Aviation meteorology has thus also been subject to intense scrutiny of its operating costs. Not only staff costs but also the operating costs of observing systems are thus under critical review and cost-effective solutions are in high demand.

2. Despite increasing economic pressure, the safety of flight remains paramount in the design and operation of aviation weather systems. A shift to a more cost-conscious design of observing and forecasting systems is nevertheless very noticeable, the days of the introduction of new systems on the grounds of increased safety regardless of cost are certainly over.

3. The trend towards fully automated observations and forecasts is slowing in some countries as the inbuilt higher safety margins required in the use of such systems has a unexpected side-effect in leading to higher numbers of IFR or alternate/below alternate conditions being reported and forecasts, leading to higher fuel costs.

4. Increased interest in the causes for delays and diversions has led to number of studies being carried out on the link between meteorological conditions and the timeliness and thus effectiveness of aviation operations at larger airports. Very large potential savings are found in some instances and may help to introduce new methods and technologies to achieve higher accuracy and reliability of observations and forecasts /warnings.

5. Time-scales in Air Traffic Management and Operations control: The required timescales for warnings and forecasts are depending on traffic density and route specifics, but are beginning to be recognized to have peaks in the very-short to short range (1 to 12 hours, in the case of intercontinental flights up to 18 hours), whereas in the warning domain, the range is beginning to increase from the typical 5-15 min range out to several hours. This increase in timescale leads to a change in requirements in the warning and forecasting methodology, shifting from the extrapolation-based methods to more model – or AI-based methods.

6. The forecasts of low visibility and ceiling conditions will for some time rely on a mix of subjective/statistical and modelling techniques. Further to these “classical” forecast problems in aeronautical meteorology, which have shown a rather limited success in improving their skill over the last decades, it is becoming clear that phenomena such as wintery conditions caused by snow, freezing precipitation and similar problems are causing considerably delays and thus high costs and need to be addressed specifically.

**Trends in Analysis, Forecast and Warning Methodologies**

7. **Forecasting of deep convection**

The most disruptive weather phenomena in tropical areas and in the mid-latitudes of the summer hemisphere are still deep convection in form of thunderstorm clusters, squall lines, mesocyclones and tornadic cells. A tendency for an increased occurrence of such phenomena due to climatic variations has been postulated by several authors recently. Higher temperatures are normally linked to a higher tropopause and thus to CB tops reaching and thus affecting even the highest available flight levels during a longer summer period at least in the northern hemisphere. A recent study linked up to 85% of turbulence incidents to convective activity, including the generation gravity waves in the vicinity (both up-and downstream) of rapidly growing cells. In developed countries, radar networks are increasingly used to identify and track convective events, and AI-techniques are being tested for skill in forecasting the movement and development of convective phenomena out to and beyond 2 hours ahead. The cross-over time to model-based forecasting techniques is currently seen at a time range of between 3 and 6 hours.

8. **Forecasting of visibility and ceiling**

The progress in the skill of visibility and ceiling forecasts has been disappointingly slow and varying between regions, seasons and climate zones. Subjective methods still prevail and require substantial training and skill on the side of forecasters. The application of direct model output has been found unsatisfactory for the required accuracy, and conventional statistical-dynamical methods again show only marginal improvements over persistence in many circumstances. AI-methods are increasingly proposed, but so far have not been able to dramatically improve the skill of conventional methods.

9. **Forecasting of "aviation impact variables ", i.e. airframe icing and high-level turbulence**

The need to forecast such phenomena for global areas out to 24 hours as part of the World area Forecasting Systems operated by ICAO maintains a high pressure on developers to relate these very small scale phenomena reliably to model parameters than can be well forecast. Significant progress has been made recently in identifying zones of icing and turbulence risk, but the classification of the risk in light, moderate or severe intensities has proven elusive.

10. **Operational impact of non-severe weather phenomena**

For many years, the main direction of research in aviation meteorology has been focussed on severe weather phenomena that have a high risk potential to the safety of aviation. In recent years, it became obvious that moderate or even light phenomena (freezing precipitation, convection, snow fall, strong winds, non-extremely low visibility and ceiling) can have a significant impact on the regularity and economy of aviation operations in regions of dense air traffic. Detection and forecasting strategies that have been developed mostly with the severe event in mind may require some re-think and even re-design to accommodate these new challenges.

**Data requirements resulting from these challenges**

11. Surface–based observations: Automated observations of temperature, humidity, wind and cloud height as well as visibility are becoming standard in most developed countries. Denser network of such observations around key airports are introduced. For the prediction of aircraft icing, the detection of freezing drizzle on the ground has proven highly relevant, and more development of automatic classification of precipitation is needed.

12. Surface-based remote sensing: Doppler weather radars continue to be a very important tool in the detection and nowcasting of deep convection. The installation of radar networks is and will be for the foreseeable future limited to highly developed countries, able to finance such a very costly network but in terms of installation and maintenance. Wind profiler networks able to detect wind shifts and boundaries in quaso-real time are highly beneficial, but again for cost and frequency allocation reasons not a viable option for global deployment.

13. Radiosondes will remain for some time the only source of profile data at very high vertical resolution, but are becoming thinned out in many regions of the world due to the high cost of their operation.

14. Aircraft data have rapidly become one of the best sources of high-quality wind and temperature data aloft, and near large airports they are also providing excellent profile data. Reduced vertical separation of aircraft to 1000ft in the upper troposphere has brought even better vertical resolution of wind data near the critical and turbulence-ridden jet levels. The

introduction of humidity sensors, which need extra investment and maintenance efforts, however, is seen as rather slow and patchy, leaving a gap in humidity observations particularly in the lower troposphere.

15. Satellite data have long been regarded as the most valuable image product for subjective nowcasting and very short range forecasting for aviation, and are only now beginning to provide input for AI-based and model applications for aviation. Their main advantages are ubiquitous availability globally, data accessibility and affordability for developing nations and steadily improving horizontal resolution in imagery and profiles.

16. The last remaining major problem for aeronautical met use of satellite data is the lack of vertical resolution and detail, which would be urgently needed in convection forecasting, and coarse profiles of humidity in the lower troposphere particularly in weather-impacted areas, where microwave sounders only can penetrate higher cloud layers. Scatterometer data hold considerable potential in tropical storm detection and forecasting over oceanic areas, and split window techniques have been vital in detecting both volcanic ash clouds and fog/low stratus cover in remote areas where surface observations are scarce. The considerable increase of channels in sounders flying on next generation Geostationary and polar orbiting satellites holds significant promise to improve vertical resolution of temperature profile information at least over cloud-free areas. Cloud motion winds continue to provide valuable information in areas where aircraft data are lacking away from major air routes, but again do not have the vertical profile quality required for the detection of vertical shear near the jet level as source of turbulence.

17. Higher temporal resolution of geostationary satellite imagery in next generation platforms increases the value of this imagery in detection regions of rapidly growing and developing convection. Increased use of AI-techniques and 4D-Variational analyses at first in large-scale models holds promise for short-range forecasting of phenomena relevant for aviation such as deep convection and rapidly developing cyclones. The use of such data in nowcasting and very-short range forecasting will require further development in variational analysis for high-resolution non-hydrostatic models, probably not operationally useable for another decade.