Sixth Meeting of CNS/MET Sub-Group of APANPIRG

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Agenda Item 14: Regional preparations for the MET Divisional Meeting (2002)

TWENTY – FIRST CENTURY FORECASTING FOR THE TERMINAL AREA

(Presented by New Zealand)

SUMMARY

This paper outlines some of the current and future developments in aeronautical meteorology, discusses future needs in the terminal area, and provides some examples of possible new information forecast products. It invites the meeting to consider how future progress can be made on delivering benefits to aviation in the terminal area from 21st century aeronautical meteorology.

1. Introduction

1.1 Weather forecasting practices have undergone a revolution in the last few decades. The use of output from global computer models is ubiquitous. High frequency and high resolution satellite imagery is available. Many countries have weather radar systems. With ever increasing computer power at affordable cost, and the availability of community mesoscale modelling systems, the stage is set for further progress in the meteorologists' abilities to nowcast and forecast weather in the terminal area in high resolution in both time and space.

1.2 Yet, aside from coding differences, the traditional weather forecasts provided to aviation for the terminal area have changed little in the last fifty years. It is time to take a serious look at what new products could be provided, in light of current and future forecasting capabilities, to meet the new and evolving needs of aviation.

1.3 Conceptually what is needed is to assess the current and future capabilities of operational aeronautical meteorology, the current and future needs of all aviation operations in the terminal area, and then to take the crucial design step of how best to produce and communicate what information.

2. Meteorological Progress

2.1 Those involved in the visionary work of the Area Forecast Panel, more than twenty years ago, looked into future likely developments in computer weather modelling and communications to design their blueprint for the World Area Forecast System.

2.2 Looking ahead a further twenty years, it is likely that a combination of new observing systems and the application of nowcasting techniques, including frequently run, very high resolution models, will revolutionise meteorologists' abilities to diagnose and predict weather in the terminal area.

Observations

2.3 Ground-based observing systems, some of which are already in place in more developed countries, include Terminal Doppler Weather Radars (TDWRs) and LIDAR. This technology will not be affordable by all countries. However, space-based remote sensing continues to improve in resolution in both time and space; frequently updated, high-resolution satellite information will be of increasingly significant assistance globally to aeronautical meteorology. Furthermore, there should be many more automated aircraft reports available, and these have the nice property of being clustered around terminal air space.

Nowcasting

2.4 Meteorologists use the term nowcasting for forecasts for the next few hours, based on a more observations-intensive approach. Traditionally, nowcasting has focussed on the analysis and extrapolation of observed meteorological fields, with a special emphasis on local and regional fields of clouds and precipitation derived from satellite and radar. Products such as extrapolated locations of microbursts and gust-fronts from TDWRs are based on automated nowcasting over time scales of a few minutes.

Numerical Modelling

2.5 Beyond a few hours, information from Numerical Weather Prediction (NWP) models is more accurate than nowcasting or extrapolation methods. By twenty years hence, this situation will change for three reasons.

2.6 First, computers will be faster and cheaper, which facilitates the other improvements.

2.7 Second, the resolution of computer models will be vastly improved. Current operational global computer models have horizontal resolutions of around 40 to 100 km; within twenty years these will probably be down to less than 10 km. Current operational local (mesoscale) models run at resolutions from a few kilometres to 20 km or so; within twenty years such local models will be down to scale of less than a kilometre - sufficient to resolve detailed local weather in the terminal area.

2.8 Third, NWP models will be run more frequently and use improved data assimilation methods, so that there is a much shorter delay from the time of the latest data until useful NWP model results are available. Current global models may perhaps be run every three hours rather than the current six-hourly runs, but more importantly the local models will be run at least hourly and perhaps even more frequently for small regions around a terminal area. In terms of data assimilation, there will be widespread use of a technique known as 4-Dimensional VARiational analysis (4DVAR), which is just now entering operational use at the more advanced modelling centres. Rather than analysing weather variables for a single time, 4DVAR is able to make use of observational information at a number of times simultaneously. 4DVAR (and its single-time equivalent 3DVAR) data assimilation methods can also make use of more unconventional data from remote sensing systems, unlike older techniques.

2.9 The net result should be improved and highly detailed model information for the terminal area, which effectively combines nowcasting and numerical modelling techniques out to many hours.

2.10 This does not mean that the forecasts will be perfect, or that the role of the human forecaster will disappear. There are sound scientific reasons (chaos theory, etc.), which limit the predictability of the atmosphere. Furthermore one of the key weather variables for aviation is the moisture content of the atmosphere (affecting clouds, precipitation, visibility, icing, stability, convection). Moisture is not well observed – future satellite systems may help, and so would automated aircraft reports of humidity. Human forecasters will continue to play a critical though changing role in assessing, monitoring, and communicating ever more complex and sophisticated information, particularly in cases of severe weather.

Forecasting in Probability Terms

2.11 Uncertainty always exists - even in our knowledge of the current state of the atmosphere. It grows chaotically in time, with forecasts at longer time ranges being increasingly uncertain. Uncertainty can be dealt with by providing forecasts in probability terms. This is already done in a somewhat crude fashion with PROB in TAFs. Forecasts of probabilities of events, or of likely ranges of parameters such as visibility or ceiling, can be done by statistical post-processing of NWP model output, as well as of course through professional judgement of forecasters.

2.12 There is another meteorological modelling trend which will facilitate probabilistic forecasting. This is the use of ensemble prediction to explicitly estimate the rate of growth of the uncertainty in a forecast. A group of forecasts - an ensemble – is run from a range of modestly different initial conditions and/or a collection of NWP models with different, but equally plausible, approximations. If the ensemble is well designed, its forecasts will span the range of likely outcomes, providing a range of patterns where uncertainties may grow. From this set of forecasts, information on probabilities can be derived automatically, tailored to users' needs. Such ensemble prediction systems are currently used primarily for forecast ranges of a few days or more, but the same principles are currently being tested on shorter-range forecasts. Within twenty-years, probabilistic short-range predictions for aviation weather elements, based on ensemble prediction, should be available.

3. Aviation Needs in the Terminal Area

3.1 The prime aviation needs will continue to be safety and efficiency.

3.2 The main safety issues are encountering hazardous weather conditions which directly or indirectly cause an accident, or having insufficient fuel to cope with weather-related delays or inability to land. The latter safety factor is related to efficiency, since it should never happen under a very conservative approach but prohibitively expensive approach of always carrying sufficient onboard fuel.

3.3 Hazardous weather conditions in the terminal area include wind shear, crosswinds, turbulence, wake vortex, thunderstorms, icing, and dust and sand storms.

3.4 Modern navigation systems increasingly mean, at least for IFR operations, that low ceilings and visibilities will not preclude a landing. However, to allow for safe operations, poor ceiling and visibility does mean lower acceptance rates of aircraft. The question is no longer “is the weather too poor for me to land?” but “is the weather too poor for me to get a slot to land?”.

3.5 Efficient operations involve both air traffic management and aircraft operations, with complex decision making processes in increasingly congested terminal airspace, as aviation traffic growth continues in spite of downturns such as those following the tragic events of September 11, 2001. Airport capacity is certainly the big issue.

3.6 To support complex decision making processes, more precision is needed in both space and time. And more information is needed on detailed weather in the vicinity of the terminal – not just single values which are applicable to the runway complex or to individual runways.

3.7 There is also a shift taking place in who are the key users for meteorological information Historically, aeronautical meteorologists have focussed mainly on the needs of pilots and of flight operations. More attention needs to be paid to the needs of Air Traffic Services, as well as the various ground operations which take place at aerodromes, such as de-icing operations.

4. Communication of Information

4.1 Annex III / WMO technical Regulations [C.3.1] sections 6.2 (Aerodrome forecasts), 6.3 (landing forecasts), 6.4 (Forecasts for takeoff), 7.5 (Aerodrome warnings) and 7.6 (Wind shear warnings) provide the current user requirements for forecasts and warnings in the terminal area. These are all text products, and in general are designed for rather coarsely defined information.

4.2 The historical problem has been that a forecaster needs to communicate, in a fairly short text message, a complex evolving weather situation. In a sense, the TAF has become a bottleneck for the communication of information. Forecasters (particularly with the assistance of models) know a lot more than they can communicate in this way, and aviation users need more detailed information, and more information on the uncertainties. In New Zealand experience, aviation users also focus very much on go/no-go decisions, and it can be difficult to determine this when a TAF gets too complicated.

4.3 A zero-based approach needs to be used to decide, given aviation needs, what forecast information needs to be communicated and in what form. Information intended to be used by humans to make short-term decisions should, eventually, be presented in primarily graphical or visual form. (The graphical presentation will probably, of course, have been derived from digital data.) Information designed to be used by automated or semi-automated systems for resource planning and management systems should be primarily text or digital data. For optimum decision making, digital data should include information on uncertainties (probabilities).

4.4 As one example of digital information, very short-range forecasts could be provided in a tabular form with each of the critical weather elements (wind direction, speed, gust, visibility/RVR, ceiling, significant weather) at fifteen minute intervals for the next three (six?) hours or so, updated every fifteen minutes. On this time scale one approach would be to ban the use of any probability information. This information could then be easily automatically processed by a user, depending on individual airport and aircraft criteria, to determine whether and what operations are expected take place, and could be presented graphically.

4.5 For longer time forecasts (and maybe even for the shorter times), probability information should be used. For example, there could be an hour-by-hour forecast from 3 or 6 out to 24 hours of the expected probability, for any point in that hour, that conditions will be worse than a specified combination of ceiling and visibility. This would allow more sophisticated and cost-effective decision-making processes for planning of flights and airport operations.

4.6 There are many other possibilities for text products, as well as graphical depictions of the weather in and around the terminal area, which will not be expanded on here, but should be studied and pursued in a visionary way.

5. Action by the meeting

5.1 The meeting is invited to

(a) Note the content, and

(b) Exchange views on the various matters discussed in this paper, and in particular how future progress can be made on delivering benefits to aviation in the terminal area from 21^{st} century aeronautical meteorology.