Session 2 – Integration, use cases, fitness for purpose and service delivery

2.2 – Terminal Area and Impact-based forecast

Probabilistic Winter Weather Nowcasting supporting Total Airport Management.

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Background of research

Winter Weather is a prominent reason for delays and cancellation of flights. It influences many airport procedures Airside and Landside of airport. The SESAR (Single European Sky ATM Research) 2020 Exploratory Research (ER) Project PNOWWA (Probabilistic Nowcasting of Winter Weather for Airports) is a joint effort of Finnish Meteorological Institute in Finland, DLR in Germany and Austro Control in Austria to create a set of Winter Weather Nowcasting product prototypes to all airport operators, which can be used as a part of joint plan in Total Airport Management.

The PNOWWA produces methods for the probabilistic short-term forecasting of winter weather and enables the assessment of the uncertainty from the end points (airports) of 4D trajectories. 4D trajectory management is an essential building block of the ICAO GANP (International Civil Aviation Organization Global Air Navigation Plan) [1] and European Single European Air (SES) concepts [2] to meet future growth in air traffic; probabilistic forecasts will be used in Air Traffic Management (ATM) applications to support operational planning in surface management and ATM decision making, thereby increasing airport capacity in critical weather situations, shortening delays and promoting safety.

In PNOWWA demonstration campaign very short-term (0-3h, "Nowcast") probabilistic winter weather forecasts at 15 min time resolution based on the extrapolation of the movement of weather radar echoes were delivered to a selected group of end users at different airports. Users were consulted to provide the most relevant parameters and operationally important thresholds of the selected parameters (e.g. how many centimeters is considered "heavy snowfall").

User needs for winter weather forecasts at airports

User needs were sought to be obtained from a wide range of aviation stakeholders mainly at airports, ranging from major hubs to smaller regional European airports. Apart from web-based surveys, direct contact was established to a number of representatives of user groups and their views and operational concepts established and compared, leading to the interesting result that any such Nowcasting system will have to be highly flexible, scalable and adaptable to meet genuinely diverse user needs. The relevant thresholds or equivalent decision criteria were discussed in face-to-face meetings with different end users at Vienna (LOWW), Innsbruck (LOWI), Zurich (LSZH), Geneva (LSGG), Rovaniemi (EFRO) and Helsinki Vantaa (EFHK) airports. Written feedback of varying detail was received from Oslo-Gardermoen, Munich, Istanbul, and Salzburg.

Three major groups of users were identified:
1. The runway maintenance needed accumulation of snow in millimetres during each 15 minute step. Thresholds were expressed separately for dry snow, wet snow and slush. In addition, they wanted a probability for freezing rain – something, what a solely weather radar –based algorithm can not express.

2. The aviation control tower wanted probability of low visibility procedures, LVP. In winter, LVP is related to clouds, fog or snowfall, and solely weather radar –based algorithm can only express the snowfall-related LVP (visibility reduction without ceiling).

3. The de-icing managers at airports used its own Deicing-weather index (DIW) PNOWWA team had experimented with this already in SESAR1 [3]. Basic idea of DIW is that the bigger DIW value is the longer time is needed for de-icing of individual aircraft. Thresholds of frost formation causing need of deicing of planes is based on the experiences of de-icing companies at Helsinki, Oslo and Stockholm airports for conditions when planes will ask for de-icing (interviews during SESAR1 projects 11.02.02. and 06.06.02). The need of individual plane’s de-icing is dependent also from the previous phases of flight and conditions it has experienced in past not only meteorological conditions.

<table>
<thead>
<tr>
<th>Weather</th>
<th>Effect on aircraft</th>
<th>DIW (De-Icing index)</th>
<th>Weather</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freezing rain/drizzle</td>
<td>Ice on plane</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Heavy snow or sleet (visibility &lt;1500 m)</td>
<td>A lot of snow on plane</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Moderate or light snow or sleet</td>
<td>Some snow on plane</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Temperature -3...+1°C and humidity &gt; 75%</td>
<td>Frost on plane</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>No remarkable contamination on plane.</td>
<td></td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

Table 1. The dependency between weather and DIW

The type of winter weather affecting mostly to airport procedures are presented in Fig. 1. In PNOWWA most important weather challenges are covered except low visibility caused by fog. Beside the nowcasting lead time of 3 hours, airport operators are interested additionally also in 12 hours, and more dominantly, in 24 hours lead times for tactical planning and pre-emptive actions. PNOWWA will concentrate to 3 hour timeframe, other tools are needed for longer forecasts.
Nowcasting methods in PNOWWA

Three nowcasting methods have been tested in PNOWWA. In the method suggested by Andersson and Ivarsson [4], wind at 850 hPa level is used to describe the movement. The wind is taken from HIRLAM (High Resolution Limited Area Model) numerical weather prediction model. This approach had been tested in SESAR1, so it was known to provide reasonable results. It was used in the first real time demonstration campaign during 2015-2016 winter.

The new nowcasting method developed in PNOWWA uses motion vector analysis scheme based on approach of optical flow [5] and the stochastic ensembles for creating probabilistic output.[6] This method was used for case studies and offline demonstrations. The method operationally used and originally developed at FMI, applies modified correlation- based atmospheric motion vector (AMV) system by EUMETSAT.[7] [8] This method was used as a benchmark for comparisons, when developing the new method.

Scientific demonstration

Simple conversion tables were used to express the dBZ values in user-defined parameters ("what is the probability, for this airport more than 10 mm snow will be accumulated 30-45 minutes from now"). Tables 2 show thresholds as used in the first scientific demo. Here all thresholds correspond with similar dBZ values, but it is also possible to choose different dBZ thresholds to each user. To select the right dBZ thresholds, type of snow had to be determined. ICAO has defined the types of snow as follows [11]

- Dry snow – can be blown if loose or compacted by hand, will fall apart again upon release.
- Wet snow – can be compacted by hand and will stick together and tend to form a snowball.
- Compacted snow – can be compressed into a solid mass that resists further compression and will hold together, or break up into lumps, if picked up.
For this application, the snow type was determined based on temperature and dew-point, read from the METAR.

<table>
<thead>
<tr>
<th>Snow accumulation mm/15 min</th>
<th>Visibility</th>
<th>DIW</th>
<th>dBz for dry snow</th>
<th>dBz for wet snow</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 10</td>
<td>&lt;=600</td>
<td></td>
<td>&gt;29.0</td>
<td>&gt;29.0</td>
</tr>
<tr>
<td>5-10</td>
<td>600-1500</td>
<td>3</td>
<td>24.5-29.0</td>
<td>23.5-29.0</td>
</tr>
<tr>
<td>1-5</td>
<td>1500-3000</td>
<td>2</td>
<td>15.5-24.5</td>
<td>19.5-23.5</td>
</tr>
<tr>
<td>&lt;1</td>
<td>&gt;3000</td>
<td></td>
<td>&lt;15.5</td>
<td>&lt;19.5</td>
</tr>
</tbody>
</table>

Table 2: Dependency between snow accumulation, visibility, DIW and radar reflectivity.

Example of end user display (web page) at one of the participating airports is in Fig. 2. Blue bars limit sections for different user groups (runway maintenance, de-icing agents tower). Horizontal axis is time in minutes since the forecast was issued. Vertical axises are severity classes of each phenomena or index, e.g. intensity of dry or wet snowfall, de-icing weather index and visibility. The colourful boxes then depict the probability of each class at each moment, largest probabilities coloured in red and yellow. In layman terms: “it is going to snow for 45 minutes more, then it’s dry for at least half an hour, probably even longer, but after 2 hours the probability of snowfall is increasing again.”
Figure 2: Example of end user online web page from 20nd February at Helsinki. Different forecast classes (left in grey) for three stakeholder groups are predicted up to 195 min. Likelihoods are color-coded.
First scientific demonstration of PNOWWA conducted for some Austrian and Finland airports during February and March 2017. There were only limited amount of real winter weather cases in Austria and Southern Finland. In Northern Finland weather was more favorable. In spite of that it was recognized that prototype worked well and it was flexible to tailor it for different users. We were able to collect valuable and positive feedback from users, which further helps to assess the applicability of probabilistic now-casting for disruptive winter weather using weather radar data.

Reference time, automatic update of web page was felt to be necessary character of product. Accumulation of snow expressed as mm/15 min scale as wished by users. Some users felt more comfortable to use traditional material than new product. It would be beneficial to give hands on familiarization to test users during some real winter weather case. That would give us more information about the level of quality of demo product and improvements, which could be done.

Users should also be well informed about the possible limitations of product. In PNOWWA prototype forecasted amount of decrease of visibility caused by snow, only. Mist or fog forecasts were not included. Users were confused with that and in operative service it should be taken into account all type of effects causing reduction of visibility. Also ATM stated the need for ceiling information in nowcasting decision support system. In current PNOWWA demonstrator forecasting of ceiling is not possible from extrapolated weather radar information. In addition to developing probabilistic forecast it is necessary to develop how probabilistic weather information could be used efficiently in ATM processes.

To demonstrate the reliability and applicability of PNOWWA product in air service provision, we have to validate and verify results and show positive impacts but also limitations. Hence, for verification we focus on last year winter events during first demonstration phase. Different weather patterns and different locations (Central Europe, Northern Europe, mountains and sea influences as well as flat areas) have been investigated.

Example of probabilistic forecast performance is given as a case of snow showers over Southern Finland 24th March 2017. Weather radar picture, probability of snow forecasts to 30 min and 120 min are shown in fig. 3. Two short snow showers were forecasted well at 30 min forecast (forecasted probabilities about 40% and even the 120 min forecast there were a hint of them (probability of snow 5-20% during showers). It is worth remarking that no false alarms were given; even there were showers in nearby areas.

Figure 3: 24th March 2017 weather radar picture, +30 and +120 min. snow forecasts. X axis shows the time of day, y axis the probability of snow. Two shower observations can be seen between 9-10 o’clock and marked as 0 at y-value = 1. The red dot marks...
Conclusions

Based on our experiences at PNOWWA it seems that with the weather radar extrapolation methods it would be possible to produce probabilistic snow nowcasts for 2-3 hours ahead. Yet there is work to be done to further develop these extrapolation methods. There is also need for close co-operation between MET and ATM stakeholders to find out the optimum way to implement probabilistic MET information to increase airport capacity, shorten delays and promote safety.

Airports have also strong need for 12-24h probabilistic winter weather information. For such purposes other methods than Radar extrapolation shall be created. In the future as influence of climate change becomes more visible, it is possible that winter storms will come more common [12]. To mitigate the effects of winter storms to aviation it is necessary to improve winter weather forecasting capabilities.

Acknowledgment

The authors would like to thank all the professionals at participating airports for their time in defining the "user needs" and providing valuable feedback. The authors gratefully acknowledge the EU grant #699221 provided by the Single European Sky Air Traffic Management Research (SESAR) Joint Undertaking (SJU) in cooperation with the EU/H2020 research program.

Web pages of project: http://pnowwa.fmi.fi

References