EXPLORATORY RESEARCH

Report of the possible solutions how probability forecast products of precipitation could increase the resilience of airport

D4.4 - RotPSHPFPoPCItRoA

PNOWWA

Grant: 699221

Call: H2020-SESAR-2015-1

Topic: Sesar-04-2015

Consortium coordinator: Finnish Meteorological Institute

Edition date: [16 May 2018]

Edition: [00.02.00]

Dissemination level PUBLIC (PU)

Founding Members

EUROPEAN UNION EUROCONTROL

SESAR JOINT UNDERTAKING

Authoring & Approval

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Document History

Edition	Date	Status	Author	Justification
00.01.00	14.3.2018	First release	Rudolf Kaltenboeck Heikki Juntti	
00.02.00	16.5.2018	Second release	Rudolf Kaltenboeck Heikki Juntti	

PNOWWA

PROBABILISTIC NOWCASTING OF WINTER WEATHER FOR AIRPORTS

This deliverable is part of a project that has received funding from the SESAR Joint Undertaking under grant agreement No 699221 under European Union’s Horizon 2020 research and innovation programme.

Abstract

Possible solutions are presented how probability forecasts products of precipitation could increase the resilience of airports. In case of non-nominal precipitation weather in winter (snow fall, freezing rain or drizzle) and in summer (flash floods, thunderstorms) probability forecasts consider intrinsic variability of weather, describe the uncertainty and help to render decision objective, depending from individual stakeholder impact factors. Within the PNOWWA project, the potential of probabilistic winter nowcasts are demonstrated. Examples are shown and referred to possible solution. Additional stakeholder PNOWWA demonstration feedback leads to new solution which are suggest.

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Abbreviations

ATM	Air Traffic Management
APOC	Airport Operation Centre
CDM	Collaborative Decision Making
PNOWWA	Probabilistic Nowcasting of Winter Weather for Airports
SESAR	Single European Sky Air Traffic Research Program

Executive Summary

PNOWWA - Probabilistic Nowcasting of Winter Weather for Airports – is a research project developing methods to support the Air Traffic Management (ATM) challenged by winter weather. In winter 2017, PNOWWA organized a real-time demonstration campaign providing to selected end-users very short-term (0-3h) probabilistic winter weather forecasts in 15 minute time resolution. The nowcasts are based on extrapolation of the movement of weather radar echoes, and ensembles are generated by adding stochastic perturbations.

In this deliverable document the possible solutions are presented on how probability forecasts products of precipitation could increase the resilience of airports. In case of non-nominal precipitation weather in winter (snow fall, freezing rain or drizzle) and in summer (flash floods, thunderstorms) probability forecasts consider intrinsic variability of weather, describe the uncertainty and help to render decision objective, depending from individual stakeholder impact factors.

Introduction

In total airport management seamless probabilistic weather information is needed from minutes to hours and days and what is more not only from airport area itself, but also toward larger areas as different approach sectors. To address the uncertainty of weather forecasts and the intrinsic variability of weather, PNOWWA has demonstrated a possible solution of probabilistic nowcasts (short range up to 3 hours) of winter weather for airports. In general, all adverse weather elements have to be included, beside winter weather, namely thunderstorms, strong wind and low visibility/ceiling evens such as fog (but these not related to precipitation).

From PNOWWA surveys, interviews, workshops and demonstration feedback possible solutions for probabilistic winter weather forecasts have been discussed with airport stakeholders and will be presented in following chapters. In this context, also probabilistic forecasts of thunderstorms (and fog) have been encouraged.

At airport environment different operators need specifically to them tailored weather information. Even in same weather situation different users have different critical thresholds how the severity of weather influences to their procedures. Different users have different capability to take risk for an adverse weather. A big advantage of presenting weather forecast in probabilistic form is that user can itself decide which level of risk he/she can accompany.

The use of probabilistic information will help to increase situational awareness for different stakeholders in all weather conditions.

1 Adverse weather accompanied by precipitation

Adverse or non-nominal weather affects airport operation in different ways in winter and summer.

1.1 Winter precipitation which affects airport operation

While severe winter weather even reduces airport safety, ordinary winter weather might already effect capacity of an airport accompanied by negative impacts to environment. In cases of strong long lasting snow falls cleaning of runways can be impossible. On shorter events timing of runway clearance, exact planning of de-icing procedures as well as flight planning is able to make the airport system more resilience.

From web-based survey [1] and individual interviews following adverse winter weather was stated by stakeholders:

- Snow fall
- Freezing rain
- Frost and freezing of wet runways
- Fog and low clouds

ATM relevant information are visibility and ceiling as well wind. For larger airports using special high capacity procedures, visibility reduction even lower than 10 km can reduce the flight rates during traffic peak hours. Airport management is most interested in snow accumulation and type of precipitation. Reduction of runway friction and landing cross-wind component are also the issues under their interest.

1.2 Summer precipitation which affects airport operation

During summer time, strong showers and thunderstorms accompanied by hazards like lighting, hail, icing, turbulence and reduced visibility are likely. Due to safety reasons, pilot deviate these areas. During risk of lightning (alert warning) ground handling will be closed to protect airside workers. ATM procedures even will be affected when suddenly wind changes occur due to thunderstorms within the surroundings.

2 Potential of probabilistic weather nowcasting

2.1 Use of probabilistic forecasts

Probabilistic forecast products of precipitation give information about the type, intensity and timing at the airport as well as the extent around the airport and surrounding in the approach area accompanied by likelihood from 0 to 100 %. An example from PNOWWA winter demonstration phases is given in Figure 1.

RUNWAY MAINTENANCE (UPDATED 2017-02-22 16:15:00 UTC)

accumulation% dry snow, mm/15min	0-15 min	15-30 min	30-45 min	45-60 min	60-75 min	75-90 min	90-105 min	105-120 min	120-135 min	135-150 min	150-165 min	165-180 min	180-195 min
over 10 mm	0	0	0	0	0	0	0	0	0	0	0	0	0
5-10 mm	60	10	0	0	0	0	0	0	0	0	0	0	0
1-5 mm	40	90	100	70	30	40	40	50	40	40	40	40	30
less than 1 mm	0	0	0	40	70	60	60	50	60	70	70	70	70
accumulation% wet snow, mm/15min	0-15 min	15-30 min	30-45 min	45-60 min	60-75 min	75-90 min	90-105 min	105-120 min	120-135 min	135-150 min	150-165 min	165-180 min	180-195 min

Figure 1: Example of PNOWWA demonstration product for dry snow accumulation showing the time-trend of dry snow occurrence for different precipitation and probability classes.

This helps for tactical short and long term planning of all activities at the airport, such as ATM, APOC, airliner and other apron operators and also public transportation to the airport. By using traditional deterministic forecasts (“yes-no” decisions), intrinsic variability of weather depending from different synoptic weather pattern, type of precipitation system and different spatial scales, would then not be considered. But this probabilistic information can be well used by customers to discriminate between different impacts to their processes at the airport depending of probability of occurrence. Stakeholders must choose proper probability thresholds, which gives them the correct balance of alert and false alarms for specific applications and increases the cost benefit. Additional, probabilistic forecast deliver objective support for user specific decision-making.

The biggest difference to former deterministic weather forecasts is, that users itself select how to interpret and assess the probability of forecasted events and possible impacts to airport operation.

3 Possible solutions of probability products

As PNOWWA is an exploratory research project the capabilities developed there are just in low maturity level and they are not validated for operational use, yet. That is why it isn't clear picture yet for all possible ways to use probabilistic products at airport and network levels. Yet in this document it is listed some ideas how them could be used and what kind benefits there could be to different users.

3.1 Solutions for all stakeholders at airports

For all stakeholders the advantages of using probabilistic forecasts are:

- Tailored meteorological information contain uncertainty information (SESAR2020 enhanced collaborative airport management)
- objective support for user specific decision making
- situational awareness even by lower occurrence of probability of different weather conditions (different impact or relevant thresholds as e.g. traffic load)
- individual user related interpretation (impact related) based on statistical analyses of historic data
- probability information show the risk of non-nominal conditions
- probability of something don't happen can also be useful. For example stop of precipitation for a while or even possibility for that.
- The use of probability information helps especially for high dense airport hub systems as part of total airport management. Weather influences all airport stakeholder in different manner, which lead to a cost benefit to all users.

Seamless probability forecasts from nowcasting time range of few hours to long-ranging forecasts up to days / 24h is necessary for tactical planning. While the focus of forecasts for ATM and APOC is few hours, airliners are additional interested in 24 hour forecasts for flight planning.

Finally, probabilistic information improves the predictability and punctuality of traffic related to SESAR ATM master plan goal [2] in particular considering environment, cost-efficiency, safety and increases the capacity of an airport.

Including weather forecast information into CDM, in particular the probability information will help airport stakeholders to address the risk and uncertainty of different weather elements and their impact to their workflow as well as possible impacts to total airport operations. Different thresholds of probability will be used by different users.

3.2 Solutions tailored to stakeholders

3.2.1 ATM

Future forecast product should provide probability information for weather elements relevant for ATM such as visibility, low clouds or rain, lighting activity and snow accumulation, which causes possible impacts on the runway capacity (reduced cross wind due to snow contamination, possible closing time of the runway for snow clearance, ….). Additional, even thunderstorms in the surrounding (not even at the airport directly) might significantly influence traffic flow patterns and causing significant delays.

Probability forecasts of areas affected by thunderstorms or significant front lines can help in ATM decision making.

For development of new ATM arrival and departure procedures, simulation can help to assess the potential of probabilistic information for different settings of individual stakeholders and their complex interactions to each other. As result, on average basis an increase of capacity accompanied by less workload should be obtained.

An example of PNOWWA demonstrator showing probability of visibility reduction due to snow fall is given in Figure 2.

TOWER (UPDATED 2017-02-22 16:15:00 UTC)

VIS decreased by snow	0-15 min	15-30 min	30-45 min	45-60 min	60-75 min	75-90 min	90-105 min	105-120 min	120-135 min	135-150 min	150-165 min	165-180 min	180-195 min
VIS less than 600 m	0	0	0	0	0	0	0	0	0	0	0	0	0
VIS 600-1500 m	60	10	0	0	0	0	0	0	0	0	0	0	0
VIS 1500-3000 m	40	90	100	70	30	40	40	50	40	40	40	40	30
VIS over 3000 m	0	0	0	40	70	60	60	50	60	70	70	70	70

Figure 2: Example of time-trend behaviour of visibility due to snow fall from PNOWWA demonstration phases.

3.2.2 Runway Maintenance

Runway maintenance is interested in most common winter weather like snow fall (timing, type of snow and intensity). But also the temperature of air and runway surface as well as humidity is essential. At the end, forecast of snow accumulation on the runway is needed to decide about cleaning and determination of status of the contamination. But also rare, high impact weather elements such as e.g. freezing rain and freezing drizzle are essential for pre-emptive actions.

Depending from factors like as e.g. traffic load (during peak hours), ability of personal and logistics (trucks, chemicals), the timing and intensity of precipitation the APOC decide when runways are cleaned or when refuelling of trucks is necessary. In this context, probability forecast helps APOC in decision making to react against adverse winter weather and for pre-emptive actions or tactical planning.

Probability forecast example from PNOWWA demonstrations phases for different types of snow accumulation classes, freezing rain and probability of freezing surface are given in Figure 3.

RUNWAY MAINTENANCE (UPDATED 2017-02-22 16:15:00 UTC)													
accumulation% dry snow, mm/15min	0-15 min	15-30 min	30-45 min	45-60 min	60-75 min	75-90 min	90-105 min	105-120 min	120-135 min	135-150 min	150-165 min	165-180 min	180-195 min
over 10 mm	0	0	0	0	0	0	0	0	0	0	0	0	0
5-10 mm	60	10	0	0	0	0	0	0	0	0	0	0	0
1-5 mm	40	90	100	70	30	40	40	50	40	40	40	40	30
less than 1 mm	0	0	0	40	70	60	60	50	60	70	70	70	70
accumulation% wet snow, mm/15min	0-15 min	15-30 min	30-45 min	45-60 min	60-75 min	75-90 min	90-105 min	105-120 min	120-135 min	135-150 min	150-165 min	165-180 min	180-195 min
over 5 mm	0	0	0	0	0	0	0	0	0	0	0	0	0
3-5 mm	0	0	0	0	0	0	0	0	0	0	0	0	0
1-2 mm	0	0	0	0	0	0	0	0	0	0	0	0	0
less than 1 mm	100	100	100	100	100	100	100	100	100	100	100	100	100
prob of freezing rain	0-15 min	15-30 min	30-45 min	45-60 min	60-75 min	75-90 min	90-105 min	105-120 min	120-135 min	135-150 min	150-165 min	165-180 min	180-195 min
prob	0	0	0	0	0	0	0	0	0	0	0	0	0
prob of freezing wet runway	0-15 min	15-30 min	30-45 min	45-60 min	60-75 min	75-90 min	90-105 min	105-120 min	120-135 min	135-150 min	150-165 min	165-180 min	180-195 min
prob	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 3: Example of time-trend behaviour of different dry and wet snow fall classes, freezing rain and the probability of freezing wet runways from PNOWWA demonstration phases.

3.2.3 De-Icing

De-icing operations need observations and forecasts of precipitation, humidity and temperature. De-Icing might be benefit in future using long and short (nowcasting) range probabilistic forecasting by tactical planning of logistics and determination of the type of de-icing liquid taking into account the uncertainty adjusted to individual impact thresholds. Additional time consuming communication between iceman and pilot can be reduced by estimation the type of de-icing liquid and adequate hold over time using additional weather information. The additional measured liquid water content can be used, but more advanced, predicted by weather radar extrapolation for the next hour to take into account possible short range changes in weather conditions.

Few airliners already introduced pre-emptive de-icing actions for aircrafts staying overnight at airports to shorten de-icing duration next day morning especially for cold or adverse winter weather conditions. Thus the use of probabilistic forecasts helps airliner to minimize costs and shorten the risk of departure delays, also relevant for smaller airports with charter traffic peaks during weekend.

An example of probabilistic forecast of the de-icing weather index for next 3 hours is given in Figure 4. This forecast can be extended for tactical planning by more than one day using data fusion of different sources such as weather radar data for short range and numerical models for long range forecasts.

DE-ICING AGENTS (UPDATED 2017-02-22 16:15:00 UTC)													
DIW class %	0-15 min	15-30 min	30-45 min	45-60 min	60-75 min	75-90 min	90-105 min	105-120 min	120-135 min	135-150 min	150-165 min	165-180 min	180-195 min
3	60	10	0	0	0	0	0	0	0	0	0	0	0
2	40	90	100	70	30	40	40	50	40	40	40	40	30
1	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	40	70	60	60	50	60	70	70	70	70
prob of freezing wet runway	0-15 min	15-30 min	30-45 min	45-60 min	60-75 min	75-90 min	90-105 min	105-120 min	120-135 min	135-150 min	150-165 min	165-180 min	180-195 min
prob	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 4: Example of time-trend behaviour of the probability for different De-Icing Weather classes and the probability of freezing wet runway from PNOWWA demonstration phases. De-Icing weather index was developed in SESAR 1.

3.2.4 Airliner

Probabilistic forecasts such as introduced in PNOWWA contain high potential for airliners flight planning to increasing cost efficiency, safety, positive environmental impacts during non-nominal winter weather. Pre-emptive flight planning keeps the capacity at an airport at higher level, especially at main hubs. E.g. the use of uncertainty of predicted winter weather (depending from probability thresholds for defined parameters) leads to cancel of fights in advance, which might increase operability of the main hub airport during severe winter weather or keeps airplane still in business. But also handle the risk of snow fall at airport by taking into account additional fuel consumptions for longer holding duration might reduce the risk of diversion. For flight planning, uncertainties in wind forecasts or areas affected by thunderstorms or organized thunderstorms can be treated in different ways. Terminal Aerodrome Forecasts already dealing with textual information using probabilities of 30 or 40 % and airliners are handling this information in individual adjusted procedures depending from weather elements such as fog or thunderstorms. Graphical information of forecasted probabilities of thunderstorm areas can help in short term deviation and also in flight planning.

3.2.5 Apron Traffic

As an outcome form interviews and stakeholder feedback, all stakeholders at the airport should have access to weather forecasts (via open platform) to anticipate adverse weather for their workflow. While package handling and passenger transportation might be affected by precipitation, fuel handling has to stop fuelling process in case of high risk of thunderstorms accompanied by lighting activity.

Thus, apron operation and passengers can assess the risk (probability) for non-nominal weather events to take preventive actions or at least be aware of possible future actions.

3.2.6 Public transportation to the airport

Open weather information platform provided by airports can present probabilistic forecasts of weather information for passengers to address the risk of severe weather events. In such cases like severe winter weather, the transportation to the airport might be interrupted or heavily delayed. Thus, for door to door entire travel concept the passenger might anticipate bad weather conditions during travel.

4 Conclusion

The use of seamless probabilistic weather forecasts will increase the resilience of airports. Users will be affected in different manner, focusing on individual aspects. Nevertheless, total airport handling taking into account the complex interactions between different stakeholders, traffic, workload, safety, economic and environmental aspects as well as pre-event conditions.

While ATM procedures for probabilistic forecasts has to be developed, airport operators (runway clearance and de-icing) and airliners can directly use improved probability forecast using proper threshold for different weather elements related to precipitation such as thunderstorm activity or winter weather forecast.

As an outlook, graphical information should be more user friendly and also providing spatial information of probability and beside that for flight planning European wide product should be made available for all airports.

References

1. PNOWWA deliverable, 2017: D4.1 “Survey of User Needs”
2. SESAR, 2015: European ATM Master Plan. (available at: https://ec.europa.eu/transport/sites/transport/files/modes/air/sesar/doc/eu-atm-master-plan-2015.pdf)