



PNOWWA

Probabilistic Nowcasting of Winter Weather for Airports

Rudolf Kaltenboeck (*Austro Control*)

Heikki Juntti, Elena Saltikoff, Harri Hohti, Kari Österberg (*FMI*)

7th SESAR Innovation Days – Belgrade
28-30 Nov 2017



Founding Members



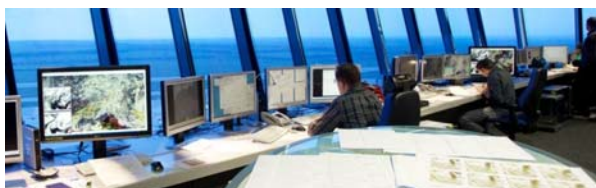
Content

1. What's PNOWWA?
2. Probabilistic winter weather forecasts at airports
3. Weather radar based nowcast methods
4. PNOWWA 1st scientific demonstrator
5. Findings and results
6. Conclusion



Winter weather at airports in PNOWWA

- Snow
- Sleet (Snow and Rain mixed)
- Freezing Rain / Drizzle
- Frost



Winter weather influences at airports

PNOWWA users



- **Runway maintenance** (runway closed, contamination)
- **De-icing**
 - need, timing
 - choose of anti-icing fluid and duration of actions
- **ATM** - Approach/Tower (capacity of airport and LVP)
- **Airliner**
 - Luggage handling, fuelling, parking, passenger ground transform etc.



Effects of adverse winter weather to airports can be mitigated to maintaining safe, punctual, efficient and environmentally friendly air traffic

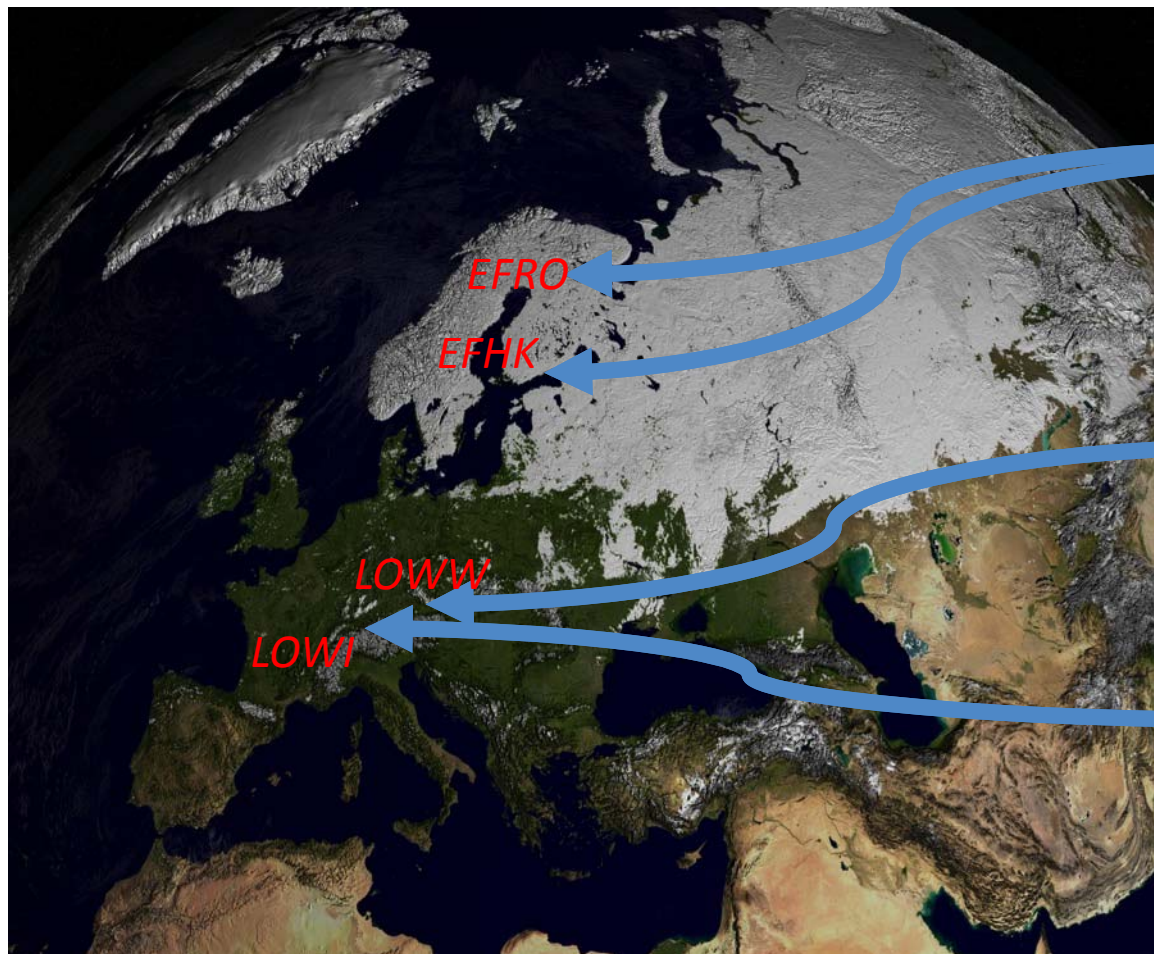


PNOWWA Objectives

1. To develop methods for **probabilistic 0-3h snow forecasts**
2. To understand impact of **mountains and sea** to snowfall
3. To identify and promote use of **probability forecasts** in variety of airport activities



PNOWWA participants



Finnish
Meteorological
Institute



Austro Control

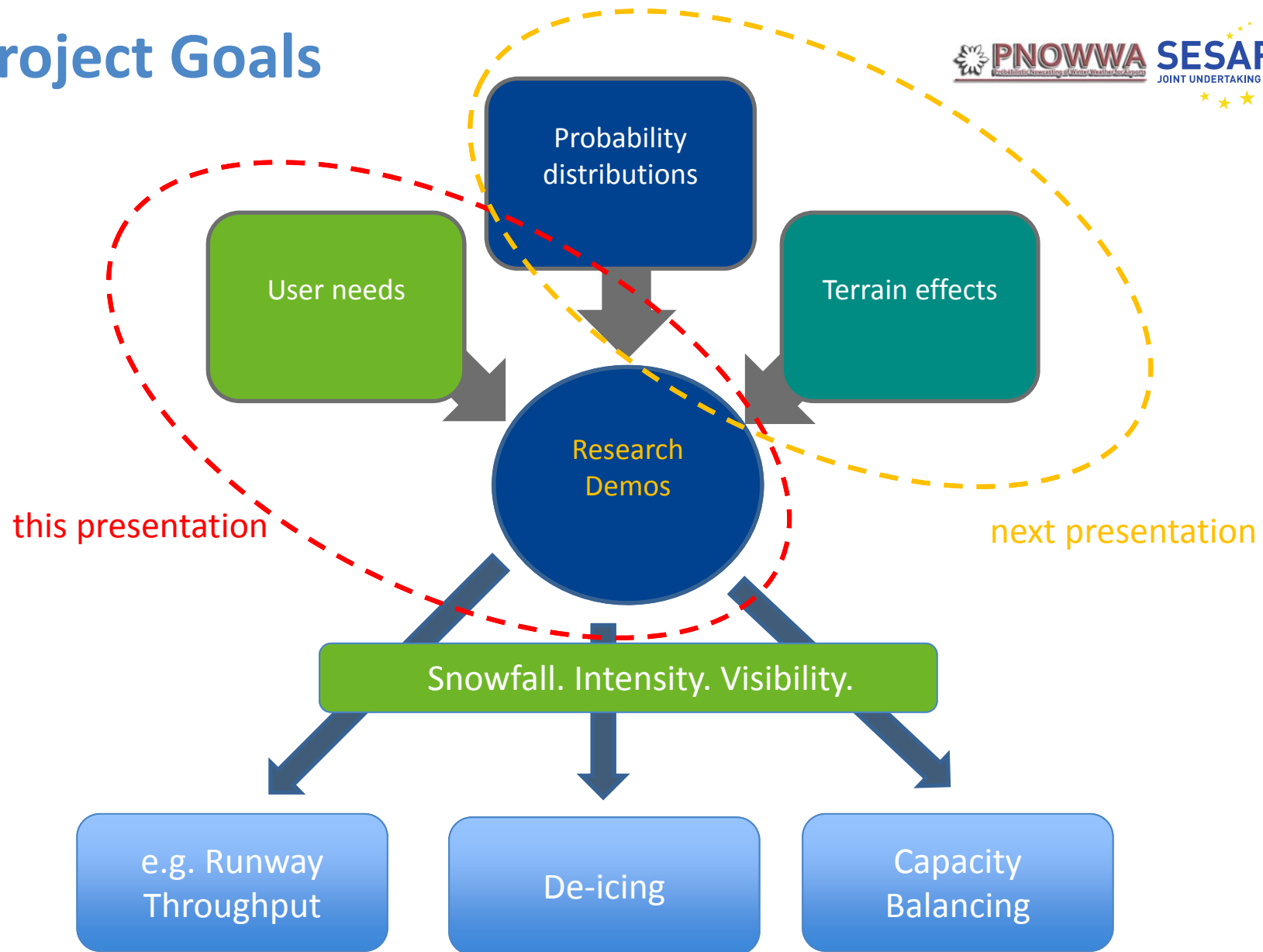


Deutsches Zentrum
für Luft- und
Raumfahrt



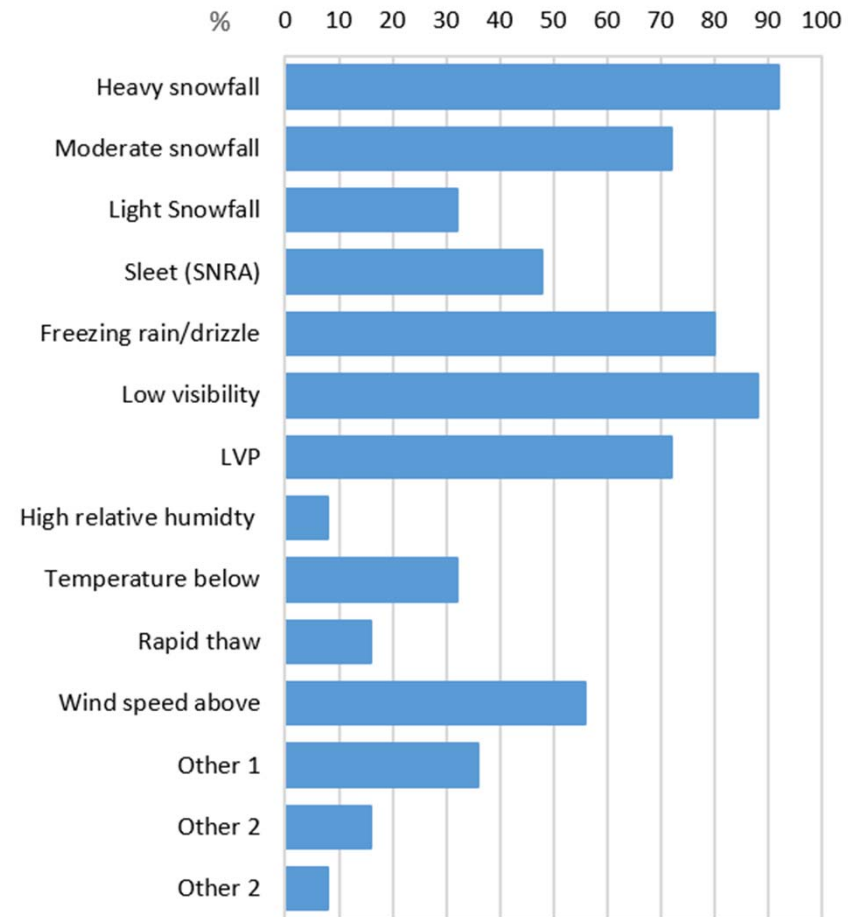
Project Goals

project overview
see poster presentation



Airport user opinions– highest negative impact affecting airport operations

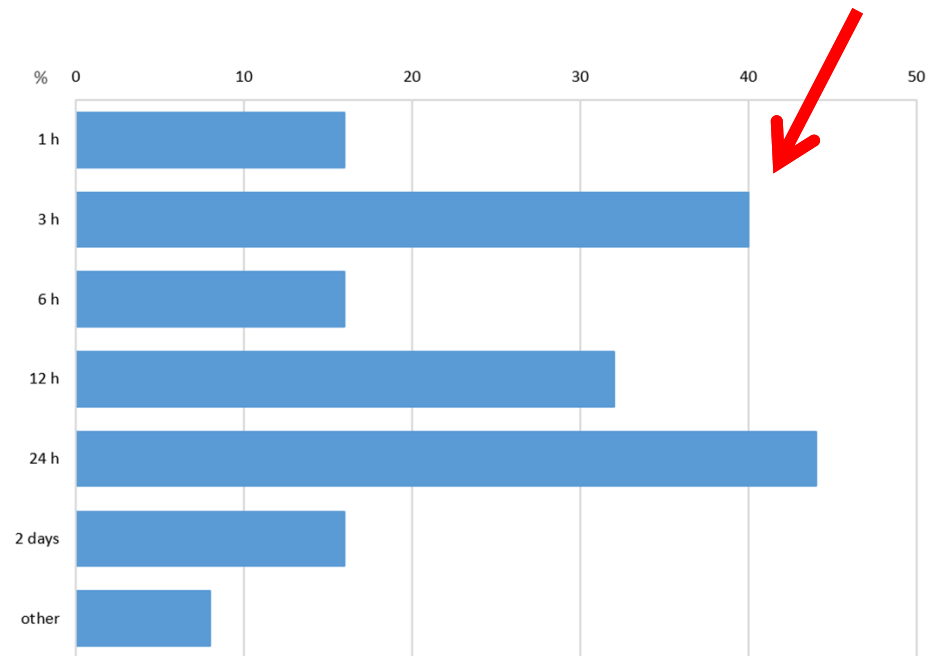
1. Heavy snowfall ←
2. (low visibility) ← -
3. Freezing rain and drizzle ←
4. Low Visibility Procedure
5. Moderate snowfall ←
6. Wind speed above
7. Sleet ←



the type of winter weather affecting negatively to airport operation (PNOWWA survey)

Airport user opinions for probabilistic winter weather forecasts – potential benefits

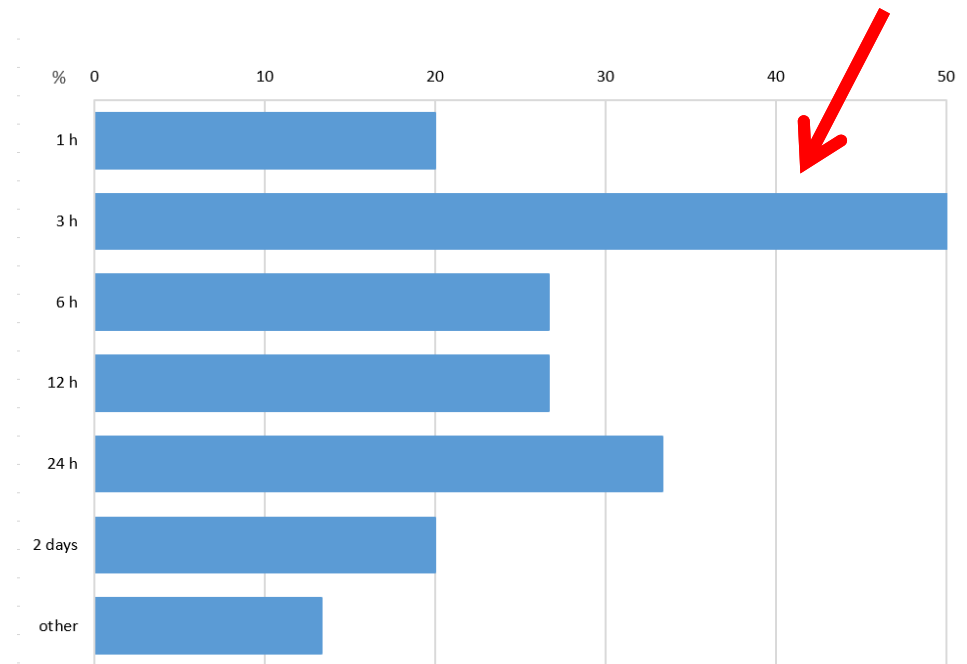
- Helps to make objective decisions
- When cost-loss ratios are known it can be used in decision support
- Positive attitude to probabilistic forecasts
- Need for lead time 3 and 12-24 hours products



Useful **lead time** for warning of critical weather for all responses (PNOWWA survey)

Airport user opinions for probabilistic winter weather forecasts – potential benefits

- Helps to make objective decisions
- When cost-loss ratios are known it can be used in decision support
- Positive attitude to probabilistic forecasts
- Need for lead time 3 and 12-24 hours products



Useful **lead time** for warning of critical weather for **ATM/Airport maintenance** group (PNOWWA survey)

Use of probabilistic forecast

- natural intrinsic **variability of weather**
- user must choose proper **probability thresholds**, which gives them the correct balance of alert and false alarms for specific applications.



- ensembles....an objective **quantity of uncertainty** results, which means increasing risk of wrong decision with lower likelihood.
- **objective** support for user specific **decision**-making processes.

Probabilistic Forecast e.g. LOWW – medium range /days

Ensembles of numerical
weather prediction model

Impact based matrix

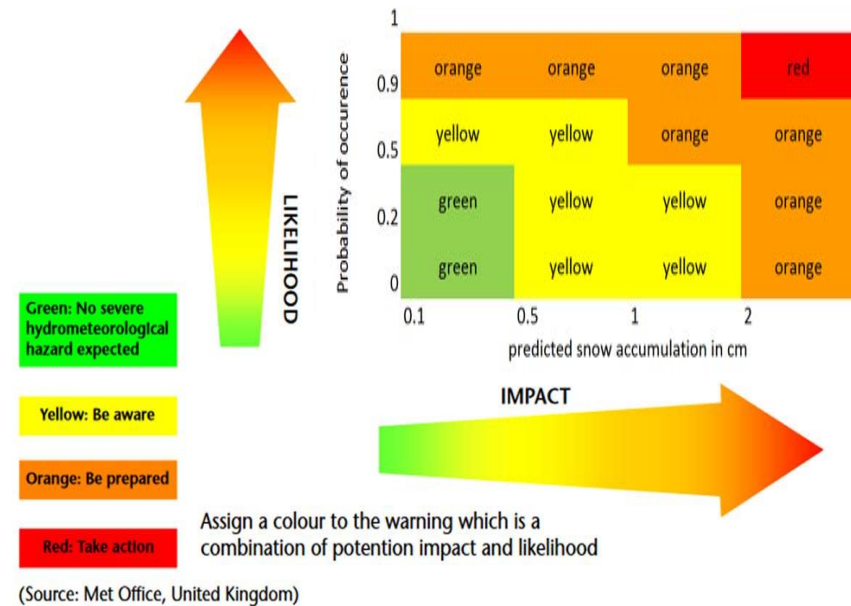
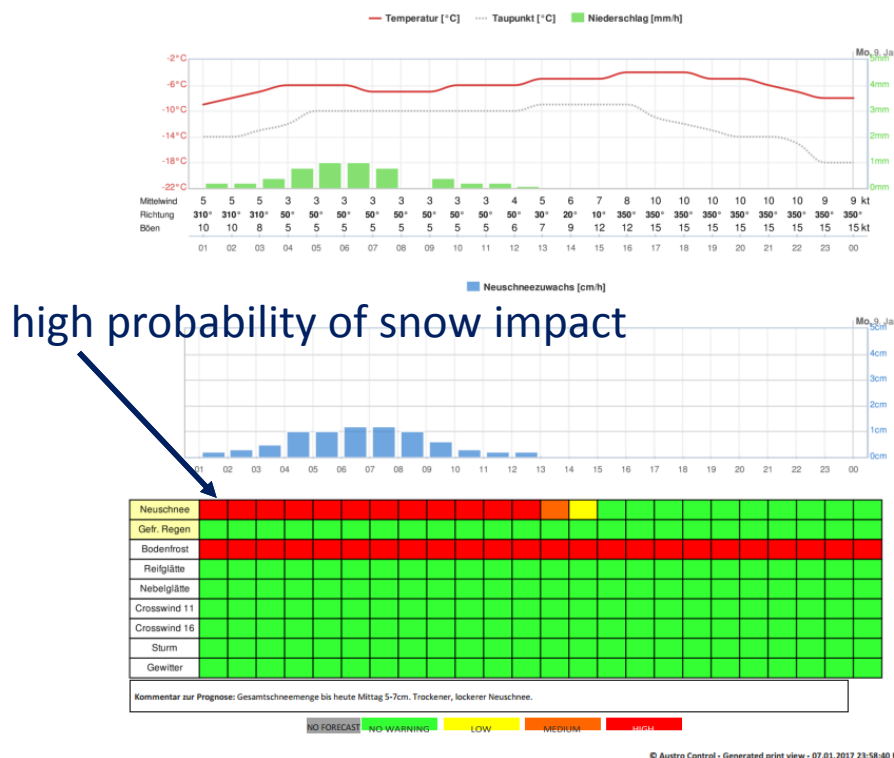


Figure 2. Risk matrix

Nowcasting

- from minutes to hours
- why do we use weather radar for nowcasting

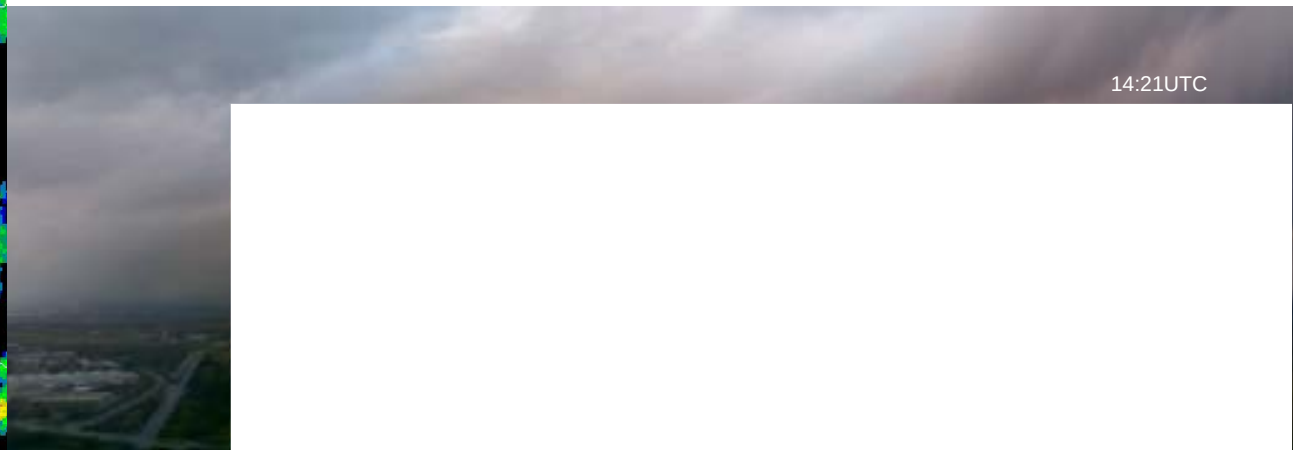
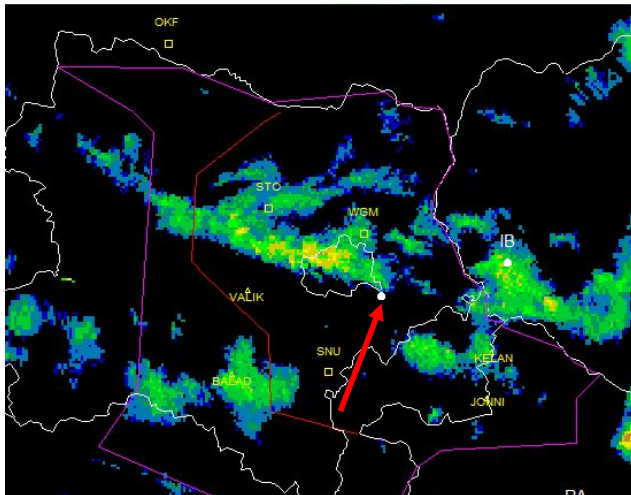
-

In short range forecasting (0-3h), exact timing is essential, because wrong timing of the adverse weather event might significantly disturb operations planning and subsequently generate substantial delays for air traffic.

- detection of existing precipitation
- weather radar has high temporal and spatial resolution over far ranges
- movement and development
- Nowcasting with extrapolation of radar images in PNOWWA
 - $\text{Time} = \text{distance} / \text{speed}$

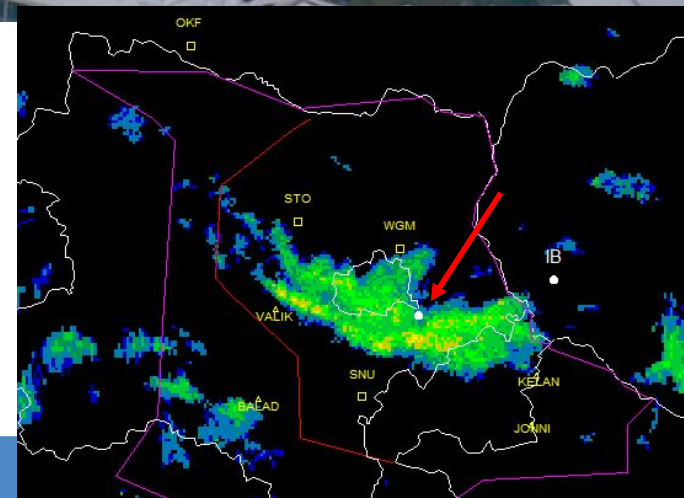
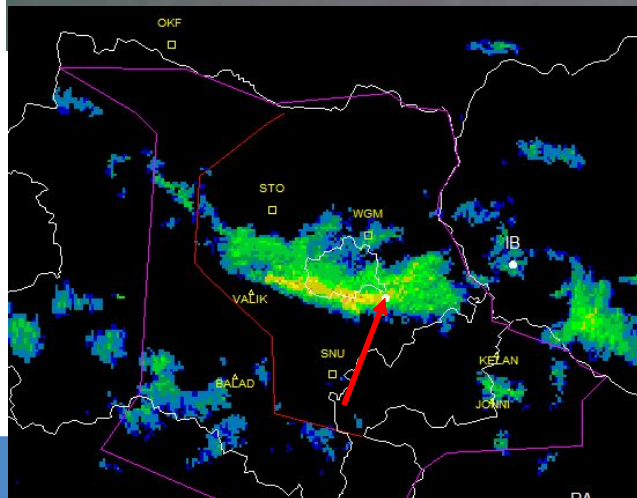
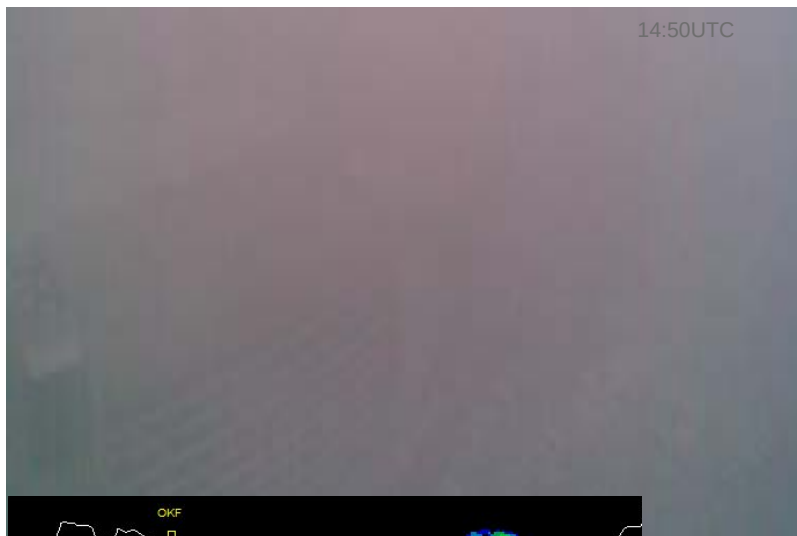
Nowcasting using weather radar winter squall line

View from Tower Vienna airport



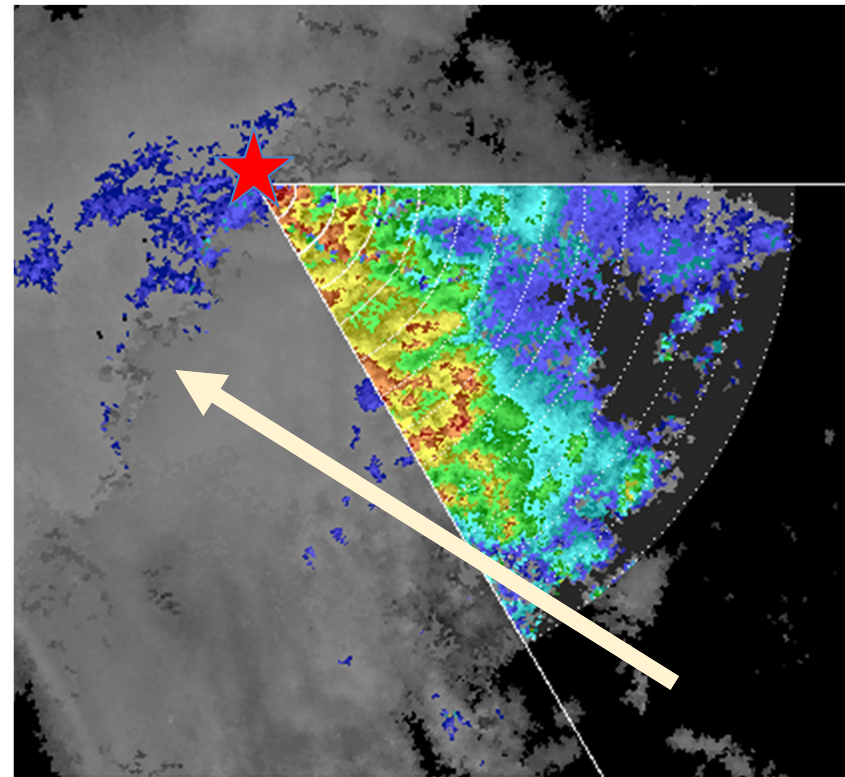
Nowcasting using weather radar winter squall line

View from Tower Vienna airport



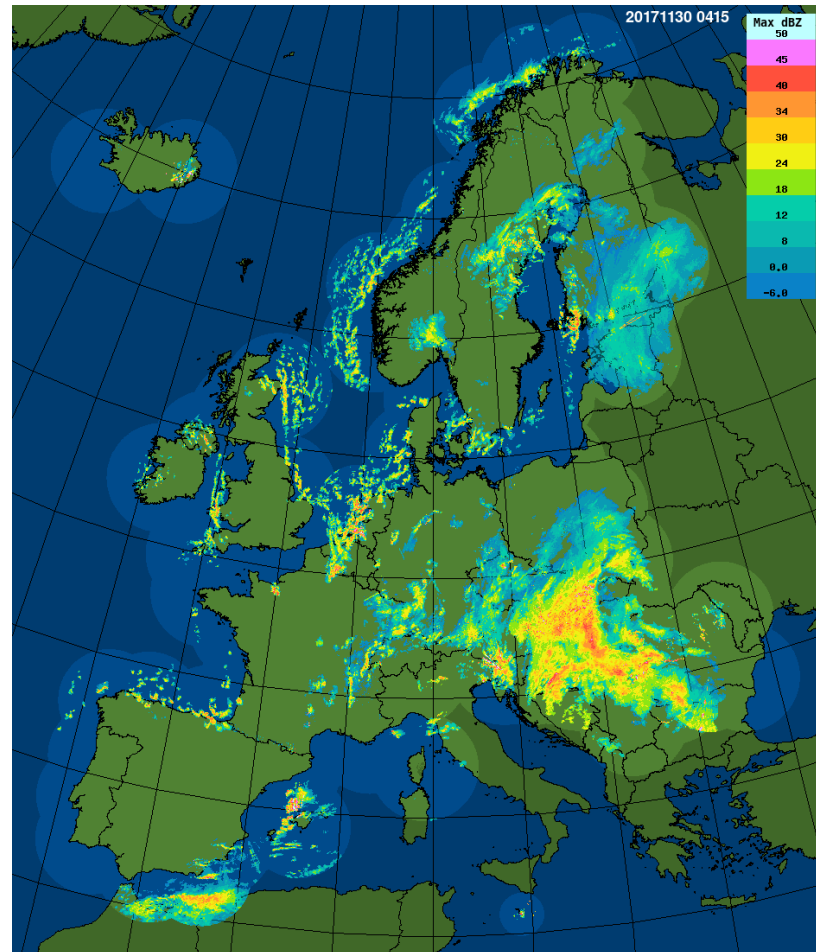
Nowcasting using weather radar Extrapolation + Ensemble Generator

- determine motion vector
- generate ensemble
 - from upflow sector texture
 - Spectral decomposition
- probability
 - deliver objective measure of uncertainty
 - growing with time, related to precip field texture



details see next presentation

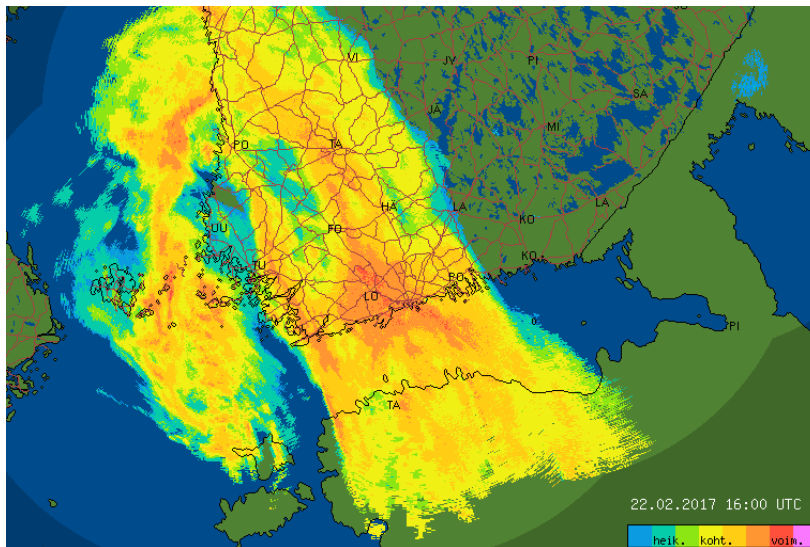
Weather radar data used in demo



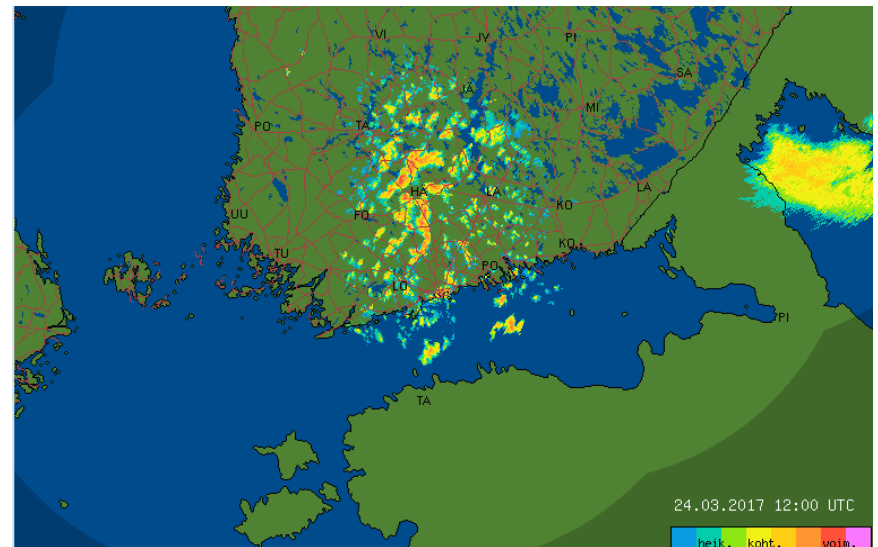
OPERA European Composite
+ Austrian data

Use of probabilistic forecast limitations

- Large synoptic systems like frontal band of snow might persist over several hours and therefore, higher probabilities in larger lead times (e.g. 120 minute) occurred in contrast to small scales of snow showers, which have a typical life time of about 60 minutes.



Frontal system hours-days



Showers minutes-1 hour

PNOWWA Scientific 1st demo

Feb/Mar 2017



- online service with automatic update (15min)
- Tailored products to:
 - Runway maintenance
 - De-icing agents
 - Tower
 - (Airliner)
- Probabilities of the weather categories defined with users
- Forecasted parameters:
 - Accumulation of DRY snow
 - Accumulation of WET snow
 - Probability of freezing rain
 - Probability of freezing of wet runways
 - De-icing weather type (categories dependent on the time of individual plane de-icing duration)
 - Decrease of visibility CAUSED BY SNOW (fog or mist outscored)

FMI Ilmanet Finanv. testikayttaja

Winter weather forecast for airports +3

EFHK EFRO

Kaikki SESAR-2020 PNOWWA -projektissa kehitetty tieto ja tuotteet on kehitetty pelkästään tieteelliseen tutkimustarkoitukseen, eikä niitä pidä käyttää missään olosuhteissa operatiiviseen palveluun. Näitä tietoja ei ole valittu tai hyväksytty sellaiseen käyttöön. Palvelun ja tiedon tuottajat eivät ole missään vastuussa palvelun soveltamattomasta tai luottamusta käytöstä tai niiden aiheuttamista asioista.

All data and products developed by the SESAR-2020 PNOWWA Project are developed purely for research purposes and shall not be used under any circumstances for operational purposes, as they have neither been validated nor designed for such use, and the authors decline any responsibility for inappropriate and unauthorized use.

Alle Daten und Produkte, die im Rahmen des SESAR-2020 Projektes PNOWWA entwickelt wurden und werden sind nur für wissenschaftliche Zwecke gedacht, und dürfen unter keinen Umständen für operationelle Zwecke verwendet werden, da sie weder dafür validiert noch designt wurden, und die Autoren jede Verantwortung für missbräuchliche Verwendung ablehnen.

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

DE-ICING AGENTS (UPDATED 2017-02-22 16:15:00 UTC)

DW 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

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

Demonstration Campaign winter 2017

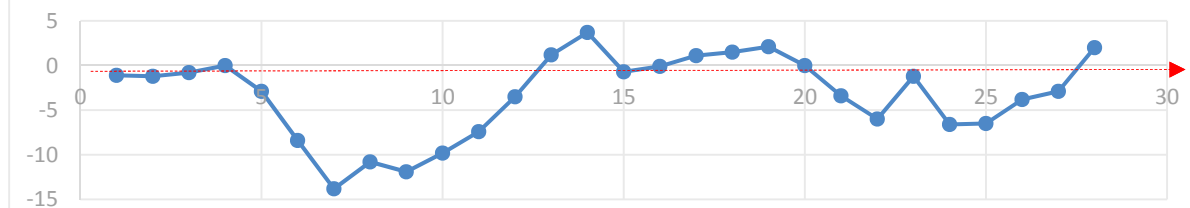
Austria – LOWW

temperature 2m [°C]



Finland:

EFHK Daily mean temperature, Feb 2017 (°C)



Demo conversion tables from radar reflectivity to forecast paramters

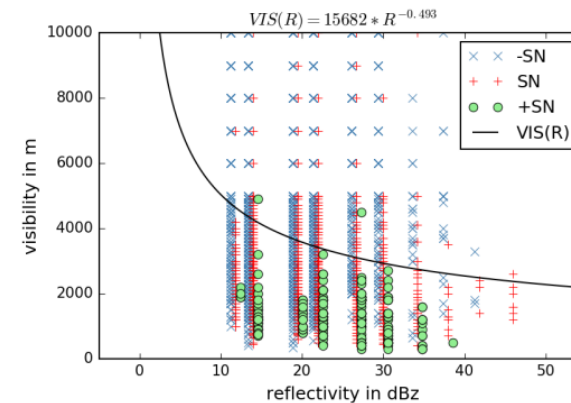
	dry snow	wet snow
Temperature in °C	≤ -0	-0 °C ≤ and ≤ +3 °C
Dewpoint in °C	≤ -1	≤ 0

Liquid water equivalent mm/h	dBZ for dry snow	dBZ for wet snow
>=4	>29.0	>29.0
2-4	24.5-29.0	23.5-29.0
0.4-2	15.5-24.5	19.5-23.5
<0.4	<15.5	<19.5

Snow accumulation mm/15 min	dBZ for dry snow	dBZ for wet snow
>10	>29.0	>29.0
5-10	24.5-29.0	23.5-29.0
1-5	15.5-24.5	19.5-23.5
<1	<15.5	<19.5

Visibility m	dBZ for dry snow	dBZ for wet snow
≤600	>29.0	>29.0
600-1500	24.5-29.0	23.5-29.0
1500-3000	15.5-24.5	19.5-23.5
>3000	<15.5	<19.5

De-icing	dBZ for dry snow	dBZ for wet snow
3	>24.5	>23.5
2	15.5-24.5	19.5-23.5



all Austrian airports – dry snowfall 2011-2017

Effect on aircraft	DIW=3, severe	DIW=2, medium	DIW=1, light	DIW=0, no need for de-icing
Ice on plane	Freezing rain/drizzle			
Snow on plane	Heavy snow or sleet, visibility cased from precipitation below 2 km, deduced from weather radar information	Light/moderate snow or sleet, visibility cased from precipitation above 2 km, deduced from weather radar information		
Frost on plane			Risk for frost formation on the plane surface. Temperature between -3.....+1 and humidity over 75%	
No remarkable contamination on plane				All other cases

Runway maintenance demo

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

	dry snow	wet snow
Temperature in °C	≤ -0	-0 °C ≤ and ≤ +3 °C
Dewpoint in °C	≤ -1	≤ 0

De-icing demo

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

De-icing time of individual airplane is directly dependent on the weather during stay of it on ground.

During weather conditions of high DIW de-icing time of aircraft is long.

DIW=3 -> ice or a lot of snow on the aircraft

DIW=2 -> some amount of snow on the aircraft

DIW=1 -> only frost on the aircraft

DIW=0 -> no de-icing need

Tower demo

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

Only influence of snow precipitation is taken into account! No fog, mist or blowing snow

Feedback – User Opinions

1st demo Feb/Mar 2017

- improvement of quality during winterquantitative verification next talk
- product description, reference time and auto updates included
- Possible limitations:
 - decrease of visibility due to snow (no fog, blowing snow...22.Feb LOWI, EFHK)
 - ATM: need of ceiling information
- probabilistic weather forecasts to help render decisions more objective
- probabilistic forecast more important for preventive actions
- preparation depends on event, likelihood and air traffic
- stakeholders are concerned about events with low likelihood which leads to no action but results e.g. in snow fall / incident
- case studies for demonstration
- Reliability (good quality, no jumps from forecast step to next step)



Feedback – User Opinions

1st demo Feb/Mar 2017

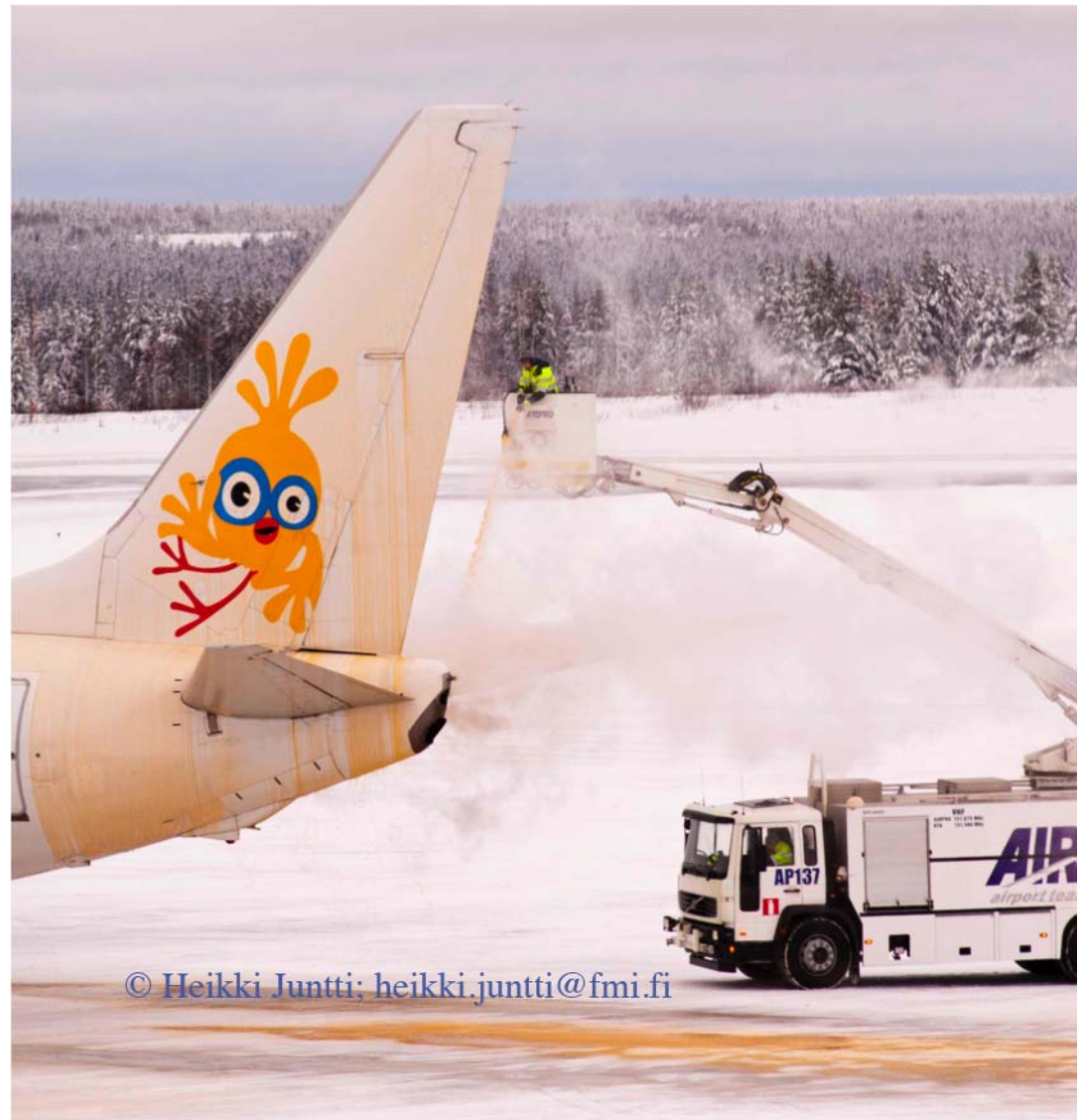
- Applicability – most useful de-icing and especially for runway maintenance
- User suggested: available to all airports in Europe
- highly flexible, scalable and adaptable nowcasting system – individual color coding
- complex interaction between different airport operations
- cost-loss vs safety.... KPI development
- nowcast of ceiling is missing
- exceedance probability instead of average probable class
- more user training and experience necessary
- Proper definition of probability-impact thresholds necessary for using in decision support systems – very sensitive
- high impact winter weather – only few events
- useful for estimation of the capacity and need of de-icing

KPI ... key performance indicator



Next steps in PNOWWA

- Second demo 12/2017 - 02/2018
- Analysis and verification of results / case studies
- Discuss with users at airports for getting more feedback during next winter
- Conclusions and recommendations
- S2020 exploratory research
- Follow-up project:
 - data fusion (NWP, 1D cloud physics, annex III products , runway temperature,...)
 - Real time application e.g. mobile app



Key Performance Indicator

- Complex interaction – stakeholder
- Traffic
- Workload
- Environment
- Economic
- Delays
- Pre-runway-conditions (chemicals, runway- temperature,)
- Safety aspects



Conclusions



- successful installation of 1st demonstrator
- Collected user feedback
- Rising awareness about probabilistic forecast
- 2nd demo ready to start1.Dec

today snowfall in Austria
online case – coffee brake



PNOWWA ... Probabilistic Nowcasting of Winter Weather for Airports

<http://pnowwa.fmi.fi>

Thank you very much
for your attention!



This project has received funding from the SESAR Joint Undertaking under the European Union's Horizon 2020 research and innovation programme under grant agreement No 699221



Founding Members

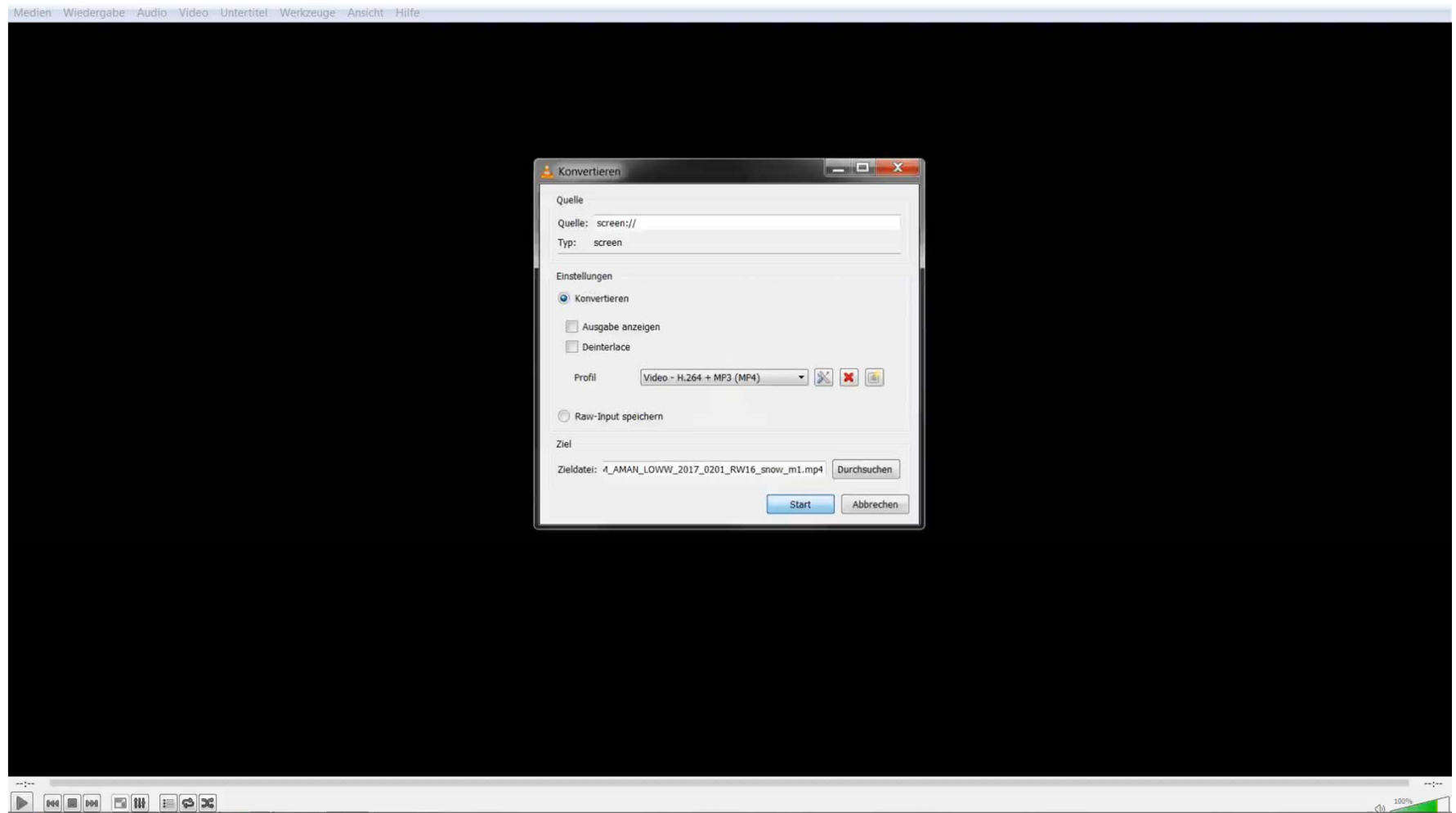


The opinions expressed herein reflect the author's view only.

Under no circumstances shall the SESAR Joint Undertaking be responsible for any use that may be made of the information contained herein.

RWY closure due to snow clearance

RWY closure on peak: 06:10 - 06:30



NAVSIM Simulation courtesy of Prof. Rokitansky