Improving snow nowcasts for airports

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PNOWWA (Probabilistic Nowcasting of Winter Weather for Airports)
Winter weather
PNOWWA Project Goals

- User needs
- Terrain effects
- Research Demos
  - Probability distributions
    - e.g. Runway Throughput
    - De-icing
    - Capacity Balancing

This Paper (nr 43)
A poster in this SID

Paper 36 in this SID
Nowcasting with extrapolation of radar images in PNOWWA

Common principle:
Time = distance/speed

Example:
storm 75 km away, moving 50 km/h arrives in 90 minutes

...dry.............. snow...maybe
Task split in two

1. Calculate the motion vectors and their uncertainty
2. Move the radar image with the vectors, assess uncertainty

In PNOWWA we have tried three methods for both.

- Simple one from 1990s (Andersson & Ivarsson 1991)
- Operational one from Finnish Met Institute (Hohti et al 2000)
- New ones in research (Proesmans et al, Pulkkinen et al.)

- (This picture related to the FMI Operational one: ellipse is related to the uncertainty of motion vectors.)
The Simple Method: Andersson & Ivarsson 1991

Frequency distribution in source area as probability distribution by time of arrival

Uncertainty of movement direction estimated as constant +/-30 degrees
The simple one was used in first demos, and it performed quite well!

EFHK
Red: Observations (15 minutes)
Green shades: 30-120 min forecasts
Even in Innsbruck, which is a challenging place for radars
"Radar is an excellent tool to say it is not raining"

Based on this image we can say that the precipitation does not start in EFJY in 2 hours. It is obvious for a meteorologist*. But it is valuable information for the snowplough driver.

*In Finland, in wintertime
Why snow? Why Airport?

Extrapolation works only for already **existing precipitation**: you cannot forecast summertime afternoon showers in the morning with these methods.

Airport is a known point with limited number of professional users.
Radar better than NWP model up to 2h
Helsinki-Vantaa, 15 minutes steps:

Hitrate, winters 2015-2016. Colours: Radar-based extrapolation TAF NWP Model
New nowcasting method based on Stochastic Ensembles: STEPS

- Motion field from consecutive radar images
- Uncertainty of motion assessed from a set of trajectories
- Uncertainty due to growth and decay modeled by a stochastic random field
A radar image is decomposed to different scales

<table>
<thead>
<tr>
<th>Large</th>
<th>Medium</th>
<th>Smallest</th>
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<tbody>
<tr>
<td><img src="image1" alt="Large Image" /></td>
<td><img src="image2" alt="Medium Image" /></td>
<td><img src="image3" alt="Smallest Image" /></td>
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<tr>
<td>Long-living features which move as they are</td>
<td>Inbetween</td>
<td>To be quickly replaced with random noise, smoothed out in output</td>
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51 ensemble members are obtained by perturbing precipitation intensities and motion field. The ensemble mean represents the "most probable" precipitation intensity. The mean field becomes smoother when the forecast time increases: badly predictable scales are filtered out. The ensembles also yield probability distributions of precipitation intensities.
Comparing two cases in STEPS (the advanced method). Time step 5 minutes, 60 min range.
Two diagram types

Reliability diagrams

- Observed frequency
- Forecasted probability
- Perfect

ROC – Relative Operating Characteristics

- Perfect
- FAR
- POD
Reliability diagrams

Plots observed frequency against the forecast probability, where the range of forecast probabilities is divided into bins (0-5%, 5-15%, 15-25%, etc.). The sample size in each bin is included as a histogram or values.

Reliability is indicated by the proximity of the plotted curve to the diagonal.
Reliability diagram 15 min

Laaja Kuurot
Reliability diagram 30 min
Reliability diagram 60 min

In widespread case, when 40-80% was forecasted, almost 100% happened: underforecasting

In the isolated showers case, even 60 min forecast almost perfect!

Small probabilities forecasted so seldomly, that this measure is not reliable
ROC – Relative Operating Characteristics

Plot hit rate or **probability of detection** against **false alarms** using set of increasing probabilities to make a yes-no decisions.

Diagonal: no skill.
Larger area above diagonal: Larger skill.

Perfect POD

**Over 5% prob = yes, snow!**

**Over 80% prob = yes, snow!**
ROC 15 min
ROC 60 min

Still very high Probability of Detection

Still very low false alarm rate
This was all radar-to-radar

Radar reflectivity is a measure of sum of diameters of particles in power of six.
So, it is related to
• Number of snowflakes in volume
• Size of snowflakes in volume
• Other microphysical properties (dielectricity) of the snowflakes

Visibility and snow depth are also related to these parameters.
But the relationship is not straightforward.

For dBZ, one 2 mm snowflake contributes as much as 64 snowflakes of 1 mm – for visibility not.
A lot of variability

From dBZ to visibility

Snow ratio: from mm to cm
Scandinavian “mountains”
Mountains

It’s complicated.
Results from hills in Scandinavia do not apply to real mountains of the Alps.

Motion vectors from radar data or the upper level wind do not explain why fronts sometimes stop.

Future: analysis of motion vector uncertainty to assess cyclogenesis
Forecasting with thresholds

- **Probability for over 5 mm**
  - Final selection

- **Probability for 1-5 mm**
  - If not, then more or less?

- **How many millimeters**
  - Not accurate anyways
Potential for follow-up projects
as identified in PNOWWA Surveys

PNOWWA is S2020
Fundamental
Exploratory Research.
To reach higher
maturity levels, more
work is needed

Data Fusion

Numerical Weather Prediction Models (EPS)

Special models (road, fog, DRSN, ...)

Annex III standard products (TAF, METAR, ...)

PNOWWA General Presentation - Saltikoff
Snow at airport

Aviation users are not afraid of probabilities

Radar is a useful tool for nowcasting
- Timing in steps of 15 minutes
- Lead times up to 2-3 hours

It is also important to forecast that it will not snow
Thank you very much for your attention!