Aviation operational nowcasting systems

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The main objective of aviation nowcasting is to increase the accuracy of high impact weather forecast that facilitate decision-making aimed at improving aerodrome capacity, efficiency and safety.

ICAO Global Aviation Navigation Plan (GANP) 2016-2030: Aviation System Block Upgrade (ASBU); Key concepts emphasize the importance of nowcasting:

- **TBO** - Trajectory-Based Operations: 4D trajectories, seamless, gate-to-gate, the most accurate trajectory, nowcasting in initial and final phases

- **MSTA** - Met Services to ATM for airport terminal area – The area mostly needs nowcasting. The closer to the area, the fine weather information is required (spatial res ~ 100 m, temporal res ~ minutes, update frequency ~ minutes)

Nowcasting is applicable at airports with heavy traffic (> 1000 take-off & landing operations) and/or many high impact weather events.
AvRDP (WMO Aviation Research and Development Project) aims

- To demonstrate the capability of nowcasting in support of the development of the next generation aviation initiative, the ASBU under the ICAO GANP
- To translate the MET information into ATM impact products so as to demonstrate the benefits of the nowcasting to the aviation community

Participants:
11 international airports incl. Saint-Petersburg (Pulkovo).
Nowcasting systems of IRAM

- Nowcasting systems **MeteoTrassa** and **MeteoExpert** have been developed and implemented with the aim to give information support to **aviation forecasters**, **aerodrome maintenance service** and **decision-makers**.
- Particular emphasis is placed on the forecasts of adverse weather conditions, relevant for **landing and takeoff**, inclusive ascent and descent, and useful for **optimization of AMAN/DMAN procedures**.
- A methodology is based on **local observations**, an adaptive **assimilation** scheme, and **numerical ABL model**.
- **Available data sources** are used incl. aviation weather observation station (**AWOS**), high frequency observing **additional automatic weather station** (**AWS**), Doppler **weather radar**, **AMDAR**, runway weather station (**RWS**).
- A radar–based algorithm has been developed to **nowcast precipitation** at res of 1 km in space and 10 min in time. A combination of a cross - correlation tracking method, averaged Doppler velocity, and prognostic wind (at 700 hPa) is employed.
Model

- The 1D ABL model represents the evolution of vertical profiles in the lower atmosphere.
- The momentum, water conservation and thermodynamic equations in terms of wind components, specific humidity, and potential temperature are written in the standard form.
- The $k-\varepsilon$ turbulence closure scheme is used which is based on the prognostic equations for TKE and EDR.
- The surface temperature is modeled with a force-restore equation, where the soil flux at the surface is given by the surface energy balance.
- The upper BC is set in accordance with GRIB-coded data from NWP model.
- Initialization: measurement data + Monin-Obukhov similarity theory, AMDAR data.
- The model provides fast and stable calculations which are required for operational use.
Nowcasting systems of IRAM

operate 24/7 and provide location-specific forecasts of the most critical weather parameters for the airport operation with lead time of 4 - 6 h and update cycle of 10 min.

**SPb (Pulkovo)**
- **MeteoExpert**
  - Aviation Meteo Center since 2018
  - **Visibility**
    - 4 hours
- **MeteoTrassa**
  - Aerodrome service since 2014
  - **Surface T and state**
    - 4 hours

**Irkutsk**
- **MeteoExpert**
  - Aviation Meteo Center since 2014
  - **Fog, visibility**
    - 6 hours

**Yuzhno-Sakhalinsk**
- **MeteoTrassa**
  - Aerodrome service since 2018
  - **Surface T and state**
    - 4 hours
Operations at the **Irkutsk airport** are significantly impacted by **low visibility** caused by **fog**. MeteoExpert has been implemented to provide forecasts of fog and visibility.

**Data input:** AWOS (1 min) and 3 additional AWSs (10 min) at fogging sites in the vicinity of the aerodrome (radius of ~5 km) for anticipating advection fog.
Tabular, graph and map data displays on workstation and the website

- Temperature profiles
- Fog forecast
- Low ceiling forecast
- Low visibility forecast
Operations at **Saint-Petersburg (Pulkovo)** airport are significantly impacted by low visibility and ceiling. MeteoExpert provides Visibility and Ceiling nowcasts.

To ensure the effective **maintenance in winter** (to keep runways, taxiways, stands free of snow and ice), MeteoTrassa provides the aerodrome service with measurements and forecasts, with emphasis on icing at the surface and precipitation.

**Data input:** AWOS KRAMS-4, AWS Saima, Doppler **weather radar**, AMDAR, RWS.
Observations and forecasts are visualized on screens of workstations and the MeteoCube website.

The 4-D MeteoCube was designed at IRAM in accordance with the ASBU concept of the 4-D database of MET information as the best choice to ensure that accurate and timely weather data would be integrated into operational decision making.
Precipitation, low ceiling and visibility

Current status – visual alarm

Precipitation 0 – 4 h

Visibility and ceiling 0 – 4 h

Color - coded in accordance with operating criteria
Case study (fog, 05.09.2018, Pulkovo) demonstrates an importance to have correct visibility forecasts for different aerodrome points, especially in inhomogeneous visibility conditions.

19:03-23:40 UTC

- Forecast: no fog at the flagged point (MKn 28R), observation: no fog (VIS > 3000 m) at the point and fog at 5 other points => forecast is correct.

23:50 UTC

Later, fog is forecasted and observed at the flagged point => forecast is correct.
Displays of recent, current and forecast weather for aerodrome service SPb

Accurate weather data and forecasts help aerodrome service to react to hazardous weather in time and to initiate preventive works.
Weather radar mosaic & wind vectors help visualize forthcoming weather.
MeteoTrassa for aerodrome service
Yuzhno-Sakhalinsk

Current weather, forecasts

Recommendations on surface treatment

Surface condition, wind

Warnings
MeteoTrassa for aerodrome service

Yuzhno-Sakhalinsk

Surface condition
T surface
T freezing
T air
T dew point
Precipitation
Visibility

Measurements and forecasts

All measurements
Verification is available on the website

- **Forecasts** have been verified **against actual observations at 10-min intervals**. **Criteria of accuracy** correspond to Annex 3 ICAO.
- **15 verification measures** are applied, incl.
  - **PC** - Proportion Correct, **F** - False alarm rate, **H** - Hit rate, **Miss** - Miss frequency...
  - **ORSS** - Odds Ratio Skill Score
  - **EDI** - Extremal Dependency Index
  - **SEDI** - Symmetrical Extremal Dependency Index

  **the most informative for forecast verification of rare events**
Fog forecast verification

for the operation period over 2015-2018 in Irkutsk

Range: [0,1]  [0,1]  [0,1]  [0,1]  [0,1]  [-1,1]

Underlined symbols correspond to ideal values
Visibility forecast verification

for the operation period over 2018.09 – 2019.03 in SPb

Visibility forecasts were verified under two thresholds (1000 and 3000m)
Conclusion

• The nowcasting system is specifically tailored to the airport needs. Impact weather parameters are to be taken into account which are most critical for the airport.

• Verification shows the reasonable accuracy of forecasts and the gradual increase of accuracy for the operation period.

• Based on the verification it can be concluded that the nowcasting systems MeteoExpert and MeteoTrassa can give real support to aviation forecasters, aerodrome maintenance service and decision-makers at the airports.

• Development of the system is the process of making algorithms gradually better, and technical component more diverse and advanced.

• New MET information about high impact weather can be translated into the ATM systems for decision-making by means of the MeteoServer (the IRAM’s system to provide ATM with MET data, > 40 systems in 6 countries)

Thank you