1. Background.

Nowcasting is usually applied as a tool to generate prognostic information with lead times of several hours for use in the issue of time-critical weather warnings. It addresses both severe weather phenomena and significant weather changes at local level. Nowcasting is applicable for meteorological providing of aviation, highways, cities, and special events of public interest like Olympic Games. Generation of accurate and timely nowcast products is a basis of early warning automated system providing information about significant weather conditions for decision-makers.

Nowcasting systems MeteoTrassa and MeteoExpert have been developed at IRAM (Institute of Radar Meteorology) and implemented with the aim to support road authorities for decision making in winter weather situations (Bazlova et al. 2014), to provide information for forecasters and decision-makers of the Olympic Game (Kiktev et al. 2017, Bazlova 2014), and to enhance airdrome situational awareness for aviation forecasters, airdrome maintenance service and decision-makers (Bazlova et al. 2016).

The MeteoTrassa system has been operational since 2011 at the Ring Highway around St. Petersburg, and since 2016 at the Western High-Speed Diameter in Saint-Petersburg. Road weather forecasts are extremely important and helpful for those responsible for managing the highways to optimize their winter maintenance activities to keep road users safe. It is vital for road maintenance decision-makers to have warnings of hazards like ice beforehand, so they can apply precautionary treatment. The MeteoTrassa transmits all required meteorological data including 4-h forecasts of surface state to the Intelligent Transport Systems (ITS) to ensure optimal traffic management.

The MeteoExpert was one of the six nowcasting systems of the FROST-2014, which was approved WMO WWRP project. The system was operational at the Main Operations Center of Sochi-2014 Olympic Games. It generated pointwise time series of meteorological variables for five Olympic venues in mountain cluster with 4-h lead time. Nowcasts have been verified against actual observations at the sites where automatic weather stations (AWS) exist with a particular emphasis on low visibility, most critical for open-air competitions and relevant for helicopter landing and takeoff (Bazlova and Bocharnikov 2017).

Nowcasting systems give relevant information support to aviation forecasters, airdrome maintenance service and decision-makers at airports with high traffic and/or many cases of high impact weather events. The nowcasting systems of IRAM operate 24/7 within three years in two airports at Russian Federation (Irkutsk and Pulkovo) and provide location-specific
forecasts with an update cycle of 10 min and lead time of 4-6 h. The systems performance is presented in this paper.


A methodology of nowcasting is based on local observations, an adaptive assimilation scheme, and numerical atmospheric boundary layer (ABL) model. All available data sources can be used including the following: aviation weather observation station (AWOS), AWS, weather radar, AMDAR, temperature profiler, road weather station (RWS), and satellite. Weather radar is one of the most important data sources in nowcasting. Radar data mosaics is useful source of information about the location and extent of convective weather. Fuzzy logic is applied to recognize convection and associated phenomena. A real-time radar–based algorithm has been developed to nowcast precipitation including its rate and type at spatial resolution of 1 km and temporal resolution of 10 min. A combination of three methods is employed to estimate precipitation movement: a cross - correlation tracking method, averaged Doppler velocity, and prognostic wind at a level of 700 hPa.

For a model to be applicable for operational use it must be reasonably accurate, relatively simple to implement, economical to run, and lead to stable calculations. The 1D ABL model is designed to represent the evolution of vertical profiles in the lower atmosphere induced by the land-atmosphere coupling and associated exchanges of energy and momentum taking place along the vertical axis. Under horizontally homogeneous conditions, and assuming incompressibility, the momentum, water conservation and thermodynamic equations in terms of potential temperature, specific humidity and wind components are written. The k-ε turbulence closure scheme is used which is based on the prognostic equations for turbulent kinetic energy and eddy dissipation rate. It enables reasonable predictions for turbulent flows. 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 net radiation flux at ground level is parameterized in a simple way including the incoming solar radiation flux on the inclined surface, the incoming long-wave radiation in terms of effective air temperature and cloud cover, and the outgoing long-wave radiation from the surface in accordance with Stephan-Boltzmann law. The differences between the surface temperature and humidity and their values at the roughness level are taken into consideration using the parameterization in terms of the Reynolds number and flux scales.

The lower boundary conditions are formulated with the aid of the Monin-Obukhov similarity theory for the atmospheric surface layer and its advanced version for the stably stratified ABL (Zilitinkevich and Esau 2007). The upper boundary conditions are set in accordance with GRIB-coded data from NWP model. Measurement data are used to set as initial conditions. The model run for each point where AWOS or AWS is installed and provide fast and stable calculations. Forecasts are generated with an update cycle of 10 min and lead time of 4-6 h.

Surface temperature and vertical profiles of the following meteorological parameters are simulated: air temperature, wind speed and direction, dew point, turbulence kinetic energy, and eddy dissipation rate. The cloud base height (ceiling) forecast is based on air temperature and humidity forecasts and the latest observational data. It is defined as the lowest level at which the humidity exceeds critical value. Visibility declining is caused by radiation extinction connected with the presence of aerosol, fog and precipitation. Visibility range is in inverse proportion with the extinction coefficient of atmosphere. In the absence of precipitation, it is in the exponential dependence on relative humidity. Visibility parameterization has been developed in terms of temperature, relative humidity, precipitation rate and type.

3. The systems.

Operations at Irkutsk airport are significantly impacted by low visibility caused by fog. The nowcasting system MeteoExpert has been implemented at the airport since August 2014
to provide the Aviation Meteorological Center (AMC) with 0-6 h forecasts of weather conditions including low visibility. Data input is used from AWOS (every 1 min) and three additional AWSs (every 10 min). Additional stations have been installed at fogging sites in the vicinity of the airdrome (radius of ~5 km) for anticipating advection fog and estimating the onset of fog at the airdrome terminal area more accurately. Forecasts for four locations and common forecast for the airdrome are provided.

At Pulkovo airport more detail information is required in order to ensure the effective maintenance in winter and to improve the airport capacity. The nowcasting system MeteoTrassa has been installed in 2014 to provide the airdrome service with a vital data for runways and taxiways maintenance. Particular emphasis is placed on the information on icing at the surface and precipitation onset. This information helps airdrome service to react to hazardous weather in time and to initiate preventive works. Measurements (including runway surface parameters) together with 4-h forecasts of icing at the surface and precipitation are provided by the system.

Next installation of the nowcasting system MeteoExpert is started at Pulkovo in November 2017 and is planned to be operational since 2018 to provide the AMC with 4-h forecasts of visibility and ceiling as most critical parameters for the airport operation.

4. The 4-D MeteoCube.

Measurements 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. The MeteoCube contains continuously updated weather observations (standard and non-standard data, ex. data from RWS), high resolution forecast information (conventional data from NWP models), and observations and forecasts of parameters relevant to aviation (convection, visibility, ceiling, icing on runways). Dual polarized data are used to derive weather radar products. The database resolution is high. Quality control algorithms are applied to ensure the correct outputs.

5. Verification.

Site specific forecasts produced by the systems have been verified against actual observations at the sites. Verification involves investigation of the properties of joint distribution of forecasts and observations for each 10 min. Data from AWSs are employed as a reference. Thresholds are chosen that are directly relevant to the customers. Criteria of accuracy correspond to operationally desirable accuracy of forecasts (Annex 3 ICAO).

Results of visibility forecast verification (under the threshold of 1000 m) over three years for the Irkutsk airport are presented in Fig. 1 in terms of Proportion Correct (PC), Hit rate (H), Miss frequency (Miss), Extremal Dependency Index (EDI), and Symmetrical Extremal Dependency Index (SEDI) (Jolliffe and Stephenson 2003, Ferro and Stephenson 2011). Onset time accuracy for hi-impact events is also estimated. Fog onset time forecast accuracy for nine months of 2017 has been calculated: standard deviation is equal to 26 min, and mean error is of 2 min. The system contributes to Terminal Aerodrome Forecast (TAF) quality improvement. According to official TAF verification, Percentage Correct of visibility forecast at the AMC Irkutsk has increased 4.2% per first year of the system operation.

Accuracy of precipitation onset 2-h forecasts at Pulkovo has been calculated for summer 2017: standard deviation is equal to 12 min, and mean error is of -3 min. Percentage Correct of 4-h forecasts of icing at the surface is of 92%.

Objective verification facilitates improvements. To improve the quality and the usage of the forecasts, the data processing algorithms (from the input data up to the output products) is constantly under development based on the verification. Fig. 1 shows the reasonable
accuracy of the forecasts and the gradual increase of forecast accuracy for the operation period.

Figure 1: Visibility forecast verification

6. Conclusion
The nowcasting system is a subject of a piecework production and is specifically tailored to the airport needs. Impact weather events are to be taken into account which are most critical for the airport. Based on the verification results it can be concluded that the nowcasting systems give real support to aviation forecasters, airdrome maintenance service and decision-makers at the airports. Development of the systems is the process of making algorithms gradually better, and technical equipment of airports more diverse and advanced.

References.