AVIAMETTELECOM OF ROSHYDROMET

NOWCASTING FOR AVIATION
IN THE RUSSIAN FEDERATION

Pulkovo (LED) airport

Pretoria, SA, 2019

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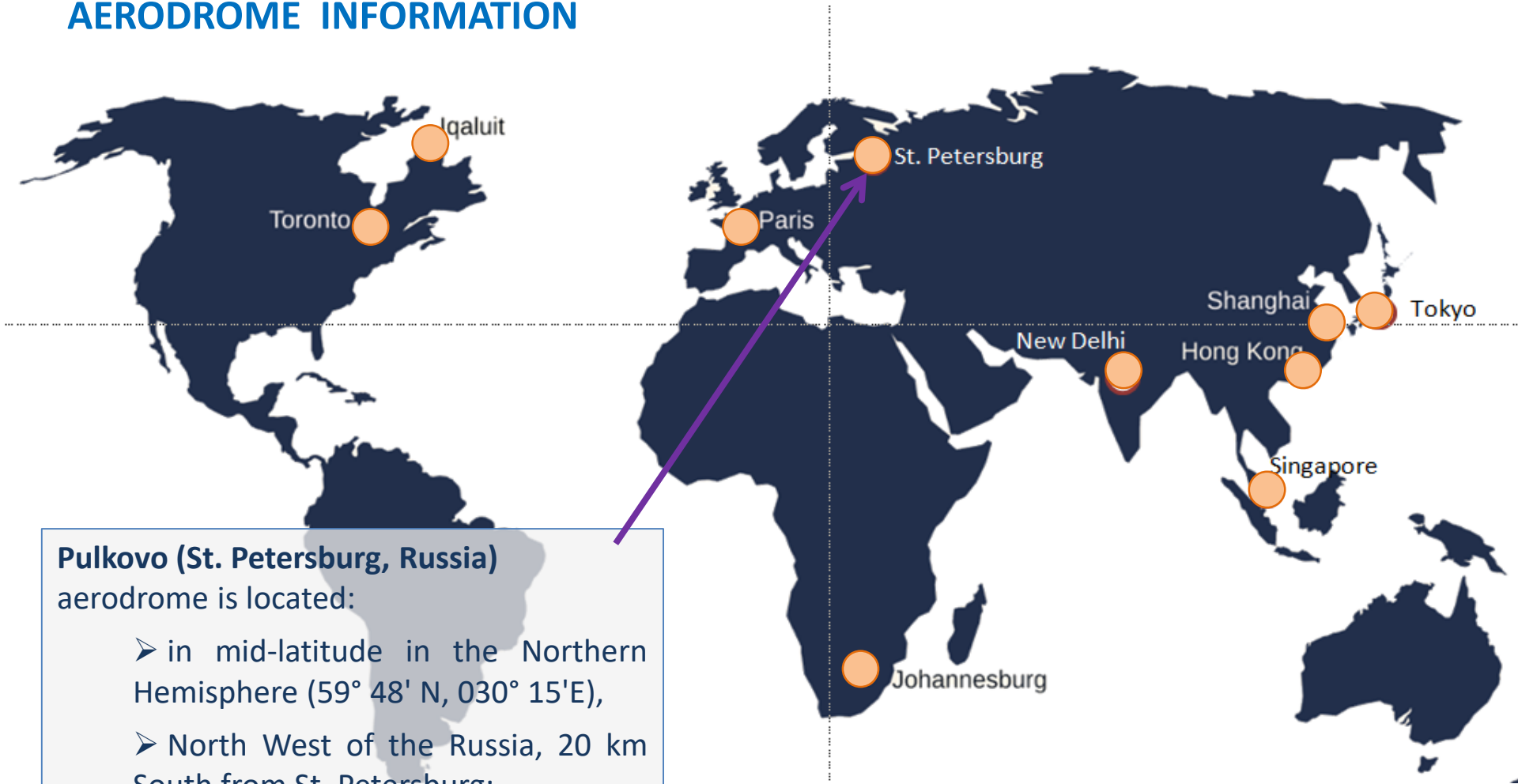
AERODROME INFORMATION



Pulkovo (St. Petersburg, Russia) aerodrome is located:

- in mid-latitude in the Northern Hemisphere (59° 48' N, 030° 15'E),
- North West of the Russia, 20 km South from St. Petersburg;

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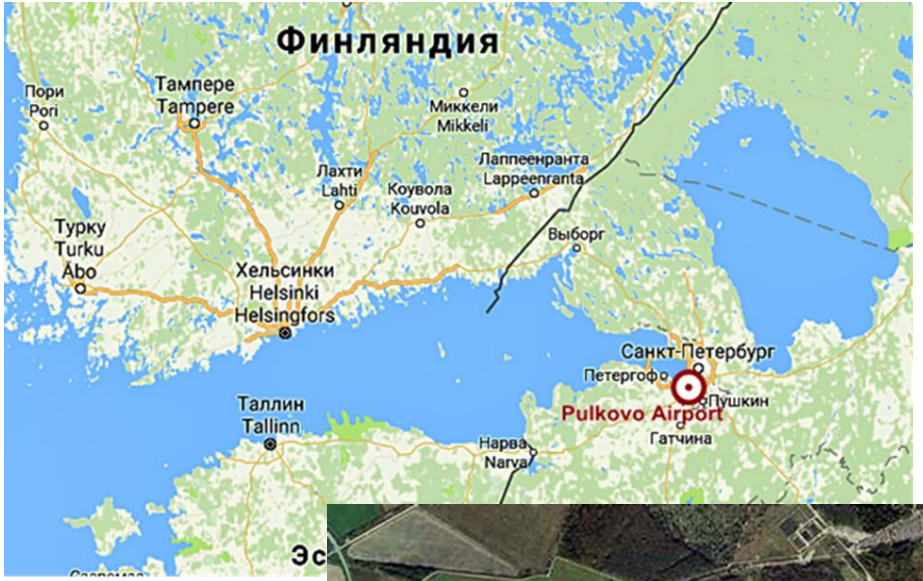
- in mid-latitude in the Northern Hemisphere (59° 48' N, 030° 15'E),
- North West of the Russia, 20 km South from St. Petersburg;
- between 2 big water reservoirs (10 km East from the Gulf of Finland and 50 km West from Ladoga Lake);
- above 24 m MSL.



The aerodrome has 2 runways:

- ✓ **10R/28L (3780 m)**
- ✓ **10L/28R (3397 m)**

CLIMATOLOGY

Pulkovo aerodrome (LED)

- transitional zone from the sea climate to continental climate
- high frequency of Atlantic air masses passing
- active cyclones and frequent changes of air masses
- unstable nature of Pulkovo weather in all seasons.

The brief **climatology of LED** for the different weather phenomena:

- ✓ the coldest month is January (average temperature is - 6.7 ° C);
- ✓ the warmest month is July (average temperature is 17.7 ° C);
- ✓ average pressure value is 1009.7 hPa (757.3 mm Hg);
- ✓ average annual precipitation amount is 603.2 mm;
- ✓ prevailing winds are in the sector from 180 ° to 270 ° (South, South-West, West).

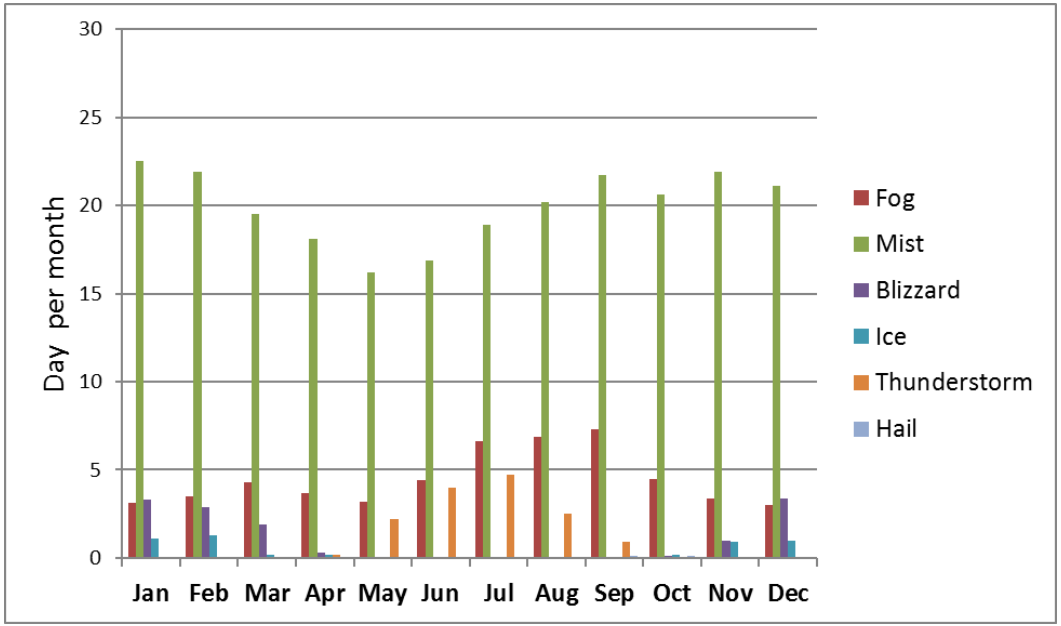
IMPACTING WEATHER

- all seasons - low visibility (caused by mists and fogs) and low ceiling,
- in winter time - heavy snow and blizzards.

That may severely slow down the normal air traffic and result in prolonged delays and even cancels of flights.

Other weather phenomena are rather rare events (the total number of observations less the 1 %) or have no significant influence on aerodrome operations and air traffic.

The **adverse weather conditions** with the low clouds and visibility are mostly observed in July-October and February - March, at night time and in the early mornings.



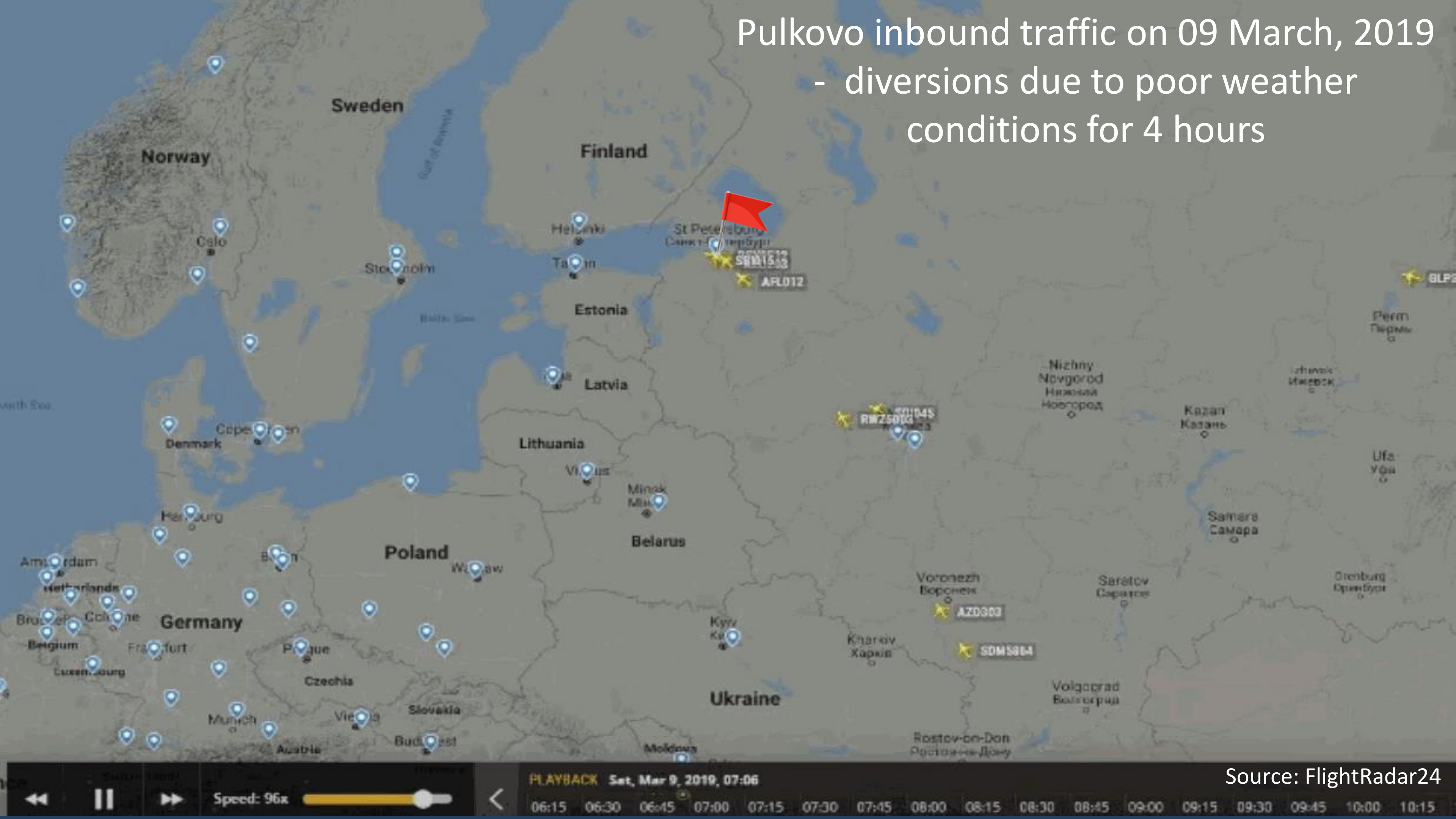
ATM/Airline/Pilot/Aviation Community Needs

Pulkovo airport *is the fourth biggest airport in the Russian Federation (165 000 flights and 18 M passengers per year 2018, +12% more in compare with the previous year).*

In operational practice at LED the periods of reduced **visibility combined with low clouds are the most frequent high impact phenomena** within a year, while the convective phenomena are seasonal and rather rare phenomena. Fog and low ceiling together determine flight category - IFR or VFR and significantly affect the work of aviation and flight safety.

Accurate and timely nowcast products are a basis of **early warning automated system** providing information about significant weather conditions (fog, low visibility, low clouds, heavy precipitation) for aviation decision-makers.

Pulkovo inbound traffic on 09 March, 2019 - diversions due to poor weather conditions for 4 hours



Source: FlightRadar24

OBJECTIVES

The **major goals** of Pulkovo aviation nowcasting:

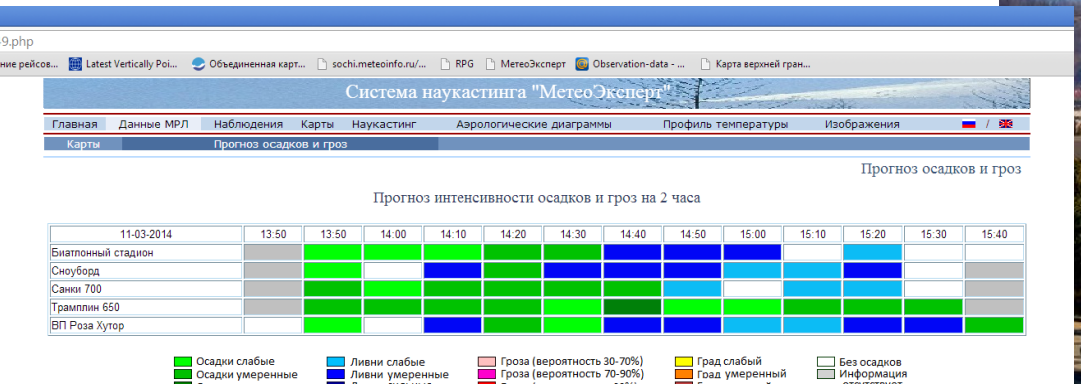
- to improve the quality of TAF/GAMET and regular pre-operating weather briefings for ATM and aerodrome operator (especially the forecasts of low visibility and low clouds),
- to demonstrate the capability and advantages of visibility and ceiling nowcasting for aerodrome operations and ATM decision making and as a result, to help in increasing of aerodrome capacity and improving flight safety.

Objectives of LED nowcasting:

- ✓ To generate 0-4 hours visibility and ceiling forecasts (nowcasts);
- ✓ To deliver nowcasts to aviation weather forecasters in real time;
- ✓ To assess accuracy of nowcasts (to verify).

STUDY APPROACH

- Visibility and ceiling nowcasting system - integral part of the Automated Information System (**AIS) «MeteoExpert**» manufactured by Institute of Radar Meteorology (IRAM).
- It functioned in the WMO project FROST-2014 during the 2014 Winter Olympic Games in Sochi and showed consistently positive results.
- In addition, since 2015 such nowcasting system has been operating at the Irkutsk airport (Siberia) **as a research polygon**.

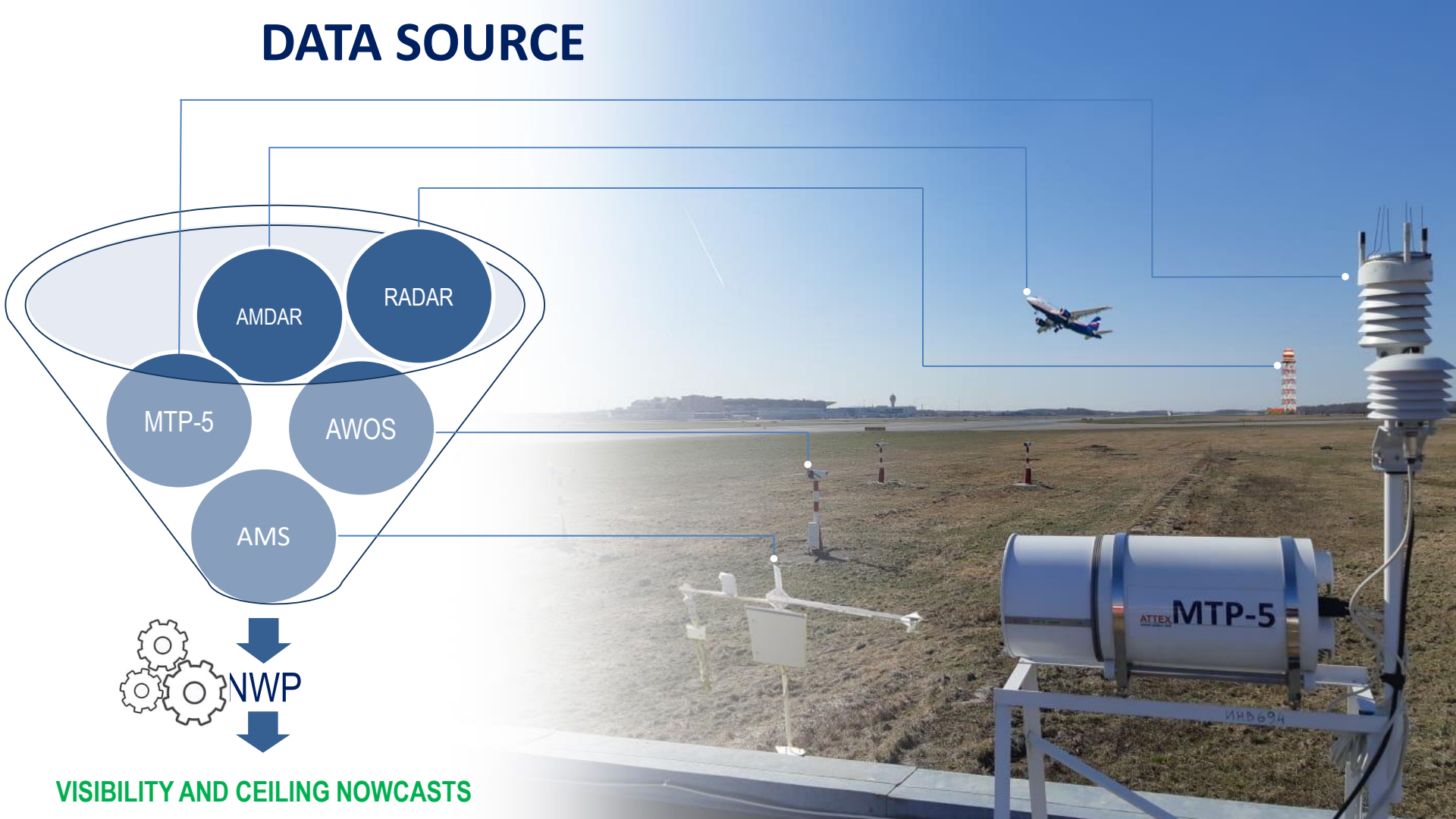


DATA SOURCE

Data sources for nowcasting system:

- ✓Pulkovo aerodrome weather observation data (**AWOS**, every 1 min) - 6 visibility sensors and 4 ceiling sensors, with the help of the automated meteorological measuring system KRAMS-4;
- ✓ Additional sensors of the automatic meteorological station **(AMS) «Saima»** installed on the MET site (pyranometers for measuring the flux of solar radiation and thermal radiation from the underlying surface, the surface temperature and the soil temperature), every 10 min;
- ✓ Atmosphere **sounding data** (by the Voeikovo station, twice a day);
- ✓ **AMDAR** data (for Pulkovo aerodrome from WMO GTS, 6-8 time a day);
- ✓ Pulkovo **Doppler radar** data + Roshydromet and BaltRad radar network (every 10 min);
- ✓ Temperature profiler **MTP-5** data (every 5 min, implemented on May 2019);
- ✓ **NWP** (4 km resolution, 1 hour update).

DATA SOURCE



VISIBILITY AND CEILING NOWCASTS

MODEL

*A **methodology** of visibility and ceiling nowcasting is based on local observations, an adaptive assimilation scheme, and numerical atmospheric boundary layer (ABL) model.*

ABL model based on the system of hydrodynamics prognostic equations of the horizontally homogeneous atmospheric boundary layer and represents the evolution of vertical profiles in the atmospheric boundary layer.

✓ The lower boundary conditions are formulated with the aid of the similarity theory.
✓ The upper boundary conditions are set in accordance with high resolution NWP data.
✓ Observations data are used to set as initial conditions.

	Биатлонный стадион	Сноуборд	Санки 700	Трамплин 650	ВП Роза Хутор
H(m)	T1(°C)	T2(°C)	T3(°C)	T4(°C)	T5(°C)
1675	-2.1	-2.1	-2.1	-2.1	-2.1
1650	-2.1	-2.0	-1.9	-1.9	-2.0
1625	-2.1	-1.9	-1.6	-1.6	-1.8
1600	-2.0	-1.8	-1.6	-1.6	-1.8
1575	-1.9	-1.7	-1.4	-1.3	-1.6
1550	-1.8	-1.5	-1.4	-1.0	-1.5
1525	-1.7	-1.4	-1.1	-1.0	-1.3
1500	-1.6	-1.4	-0.9	-0.8	-1.2
1475	-1.6	-1.2	-0.7	-0.5	-1.1
1450	-1.4	-1.1	-0.7	-0.5	-0.9
1425	–	-1.0	-0.4	-0.3	-0.7
1400	–	-0.9	-0.2	-0.1	-0.6
1375	–	-0.7	0.0	0.1	-0.4
1350	–	-0.6	0.0	0.3	-0.3
1325	–	-0.6	0.2	0.3	-0.1
1300	–	-0.4	0.3	0.5	0.0
1275	–	-0.3	0.5	0.7	0.2
1250	–	-0.2	0.7	0.9	0.3
1225	–	-0.1	0.8	1.1	0.4
1200	–	0.0	1.0	1.2	0.6
1175	–	0.2	1.1	1.4	0.7
1150	–	0.3	1.3	1.7	0.9
1125	–	0.4	1.6	1.8	1.0
1100	–	0.5	1.7	2.0	1.1
1075	–	0.6	1.8	2.1	1.3
1050	–	0.7	1.9	2.4	1.4
1025	–	1.0	2.1	2.5	1.6
1000	–	–	2.3	2.7	1.7
975	–	–	2.4	2.9	1.9
950	–	–	2.6	3.0	2.0
925	–	–	2.8	3.2	2.0
900	–	–	2.9	3.4	1.9
875	–	–	3.1	3.5	–
850	–	–	3.3	3.7	–
825	–	–	3.4	3.9	–
800	–	–	3.6	4.1	–
775	–	–	3.7	4.2	–
750	–	–	3.9	4.4	–
725	–	–	4.1	4.6	–
700	–	–	4.1	4.8	–

PROGNOSTIC VARIABLES

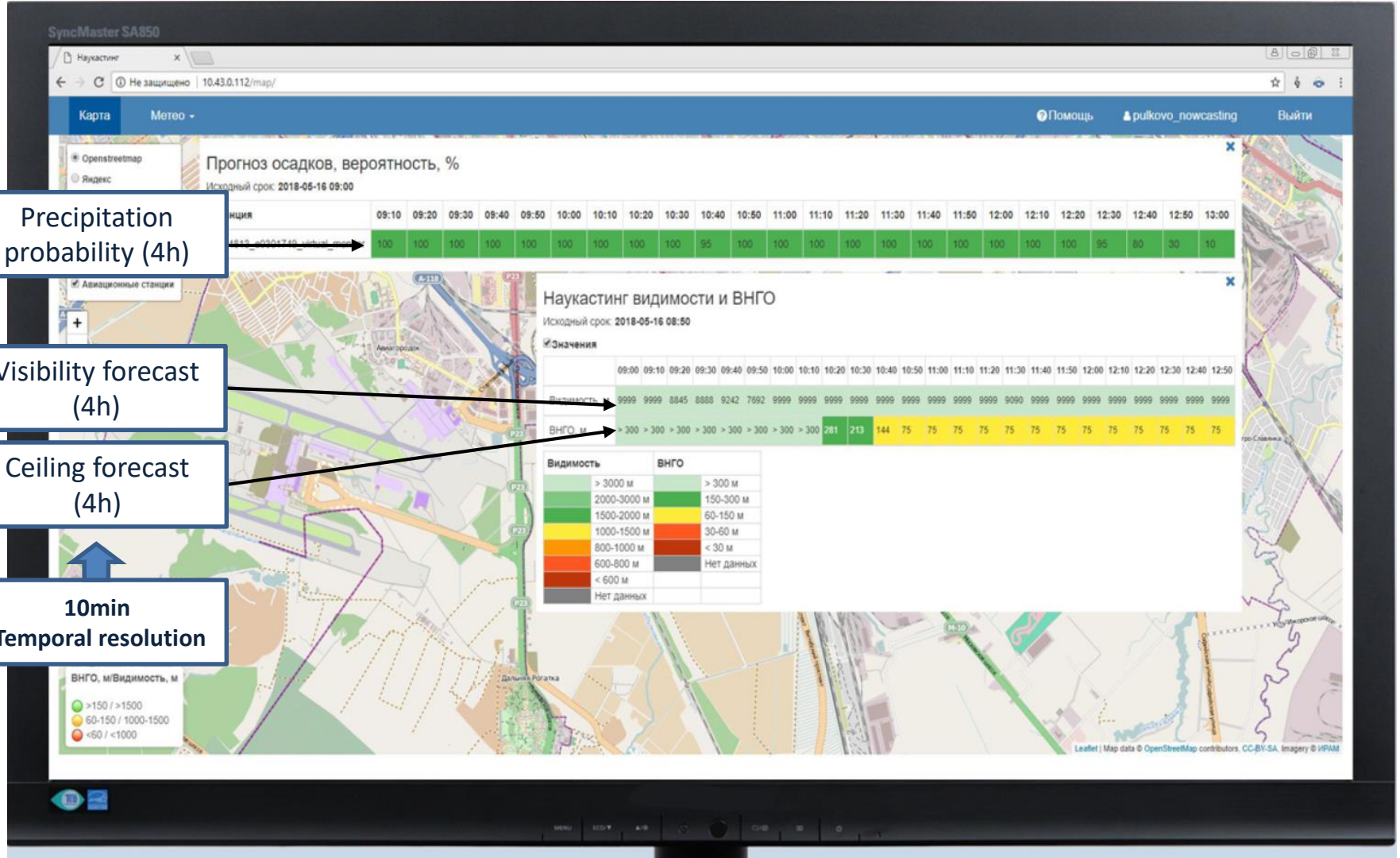
- ✓ vertical profiles of wind speed and direction,
- ✓ vertical profiles of air temperature and humidity,
- ✓ kinetic energy of turbulence and dissipation rate of turbulent energy,
- ✓ surface temperature.

➢ **Ceiling** forecast is based on prognostic profiles of temperature and humidity and latest observational data. It is defined as the lowest level at which the humidity exceeds critical values.

➢ **Visibility** forecast - parametrization in terms of relative humidity, type and intensity of precipitation, based on the dependence of visibility range on the attenuation coefficient of the atmosphere, taking into account the aerodrome climatological data.

➢ Nowcasting of **precipitation type and intensity** using dual-polarization radar data is based on extrapolation of Doppler radar data. This information is valuable itself and at the same time can result in visibility parameterization improvement.

➢ **Advection** is also taken into account in some way to consider fog transfer to an airdrome area from foggy sites where additional automatic weather stations are installed.


Precipitation probability (4h)
Visibility forecast (4h)
Ceiling forecast (4h)
10min
Temporal resolution
Карта
Метео
Помощь
pulkovo_nowcasting
Выйти
Прогноз осадков, вероятность, %
Наукастинг видимости и ВНГО
Видимость
ВНГО
ВНГО, м/Видимость, м

NOWCASTING SYSTEM

- ✓ utilizes the latest observation data and updates every 10 minutes,
- ✓ produces 0-4 hours visibility and ceiling nowcasts and precipitation probability at 10 min intervals.

The nowcasting system comprises the following blocks:

- ➢ Observation data receiving and processing for visibility and ceiling nowcasting;
- ➢ Doppler weather radar data receiving and processing for precipitation nowcasting;
- ➢ Forecasting of meteorological variables on the basis of ABL model,
- ➢ Database for data storage;
- ➢ Specialised Web-site for data visualization.

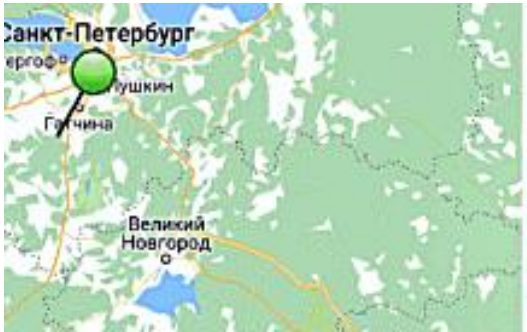
DATABASE AND VISUALIZATION

➢ Monitoring and recording of observations and nowcasts in the archive and in the database is carried out at the **specialized web-site and database** for data storage. To ensure the protection of information, an authorization system is used.

➢ Observation and nowcasts are visualised in **graphs and categorical tabular format**.

➢The colour code is used in accordance with operational criteria (criteria for SPECI, TAF AMD, TREND from Annex 3 ICAO):

- ✓ visibility: 3000, 2000, 1500, 1000, 800 and 600 m;
- ✓ ceiling: 300, 150, 60 and 30 m.



Видимость, м		ВНГО, м	
	> 3000		> 300
	2000-3000		150-300
	1500-2000		60-150
	1000-1500		30-60
	800-1000		< 30
	600-800 м		Нет данных
	< 600		
	Нет данных		

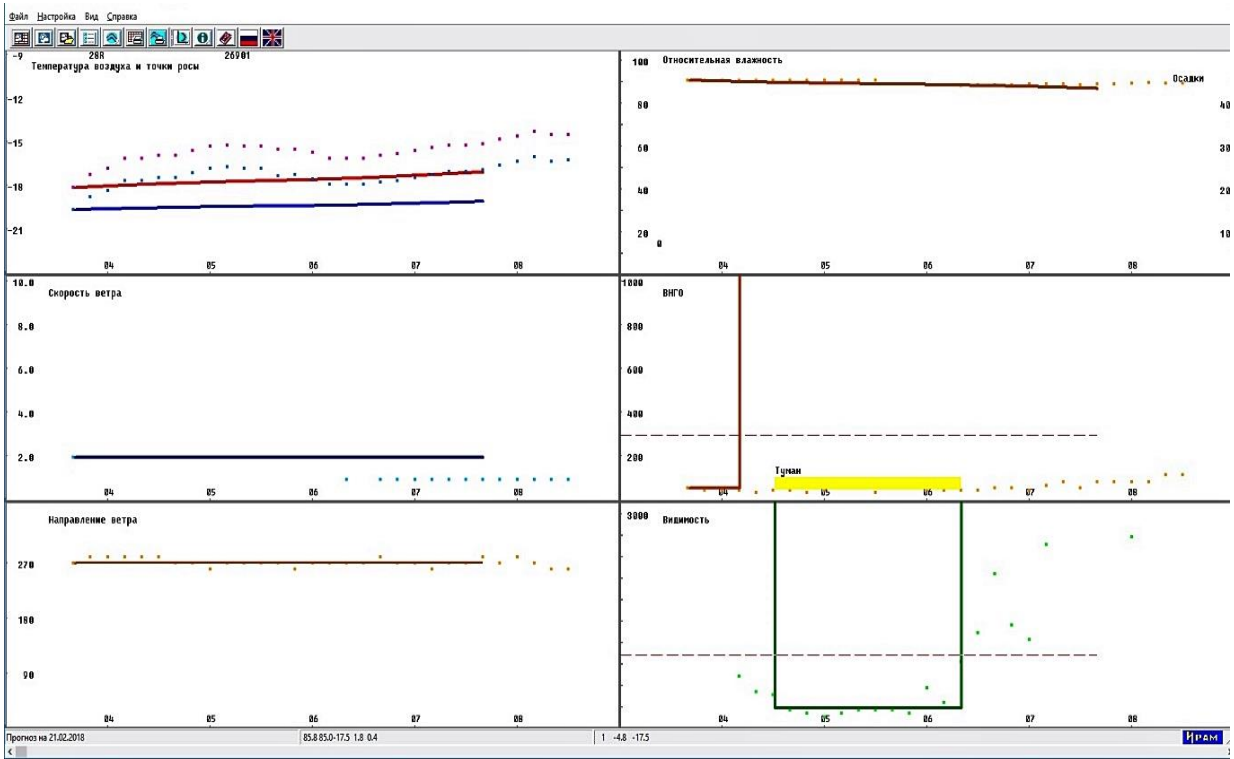
1st IOP – 01.02.2018 – 31.05.2018

- Basic nowcasting system is developed for the data from **one point of aerodrome** (meteorological observational site with an additional AWS station – MET site).
- The work of MeteoExpert visibility and ceiling nowcasting system is performed for 4h ahead at 10-min intervals. **The real-time delivery** of observations and nowcasts to weather forecasters was implemented.
- **Methods of verification** (evaluation) of nowcasting results was determined, the verification methodology was developed by the joint efforts of Aviamettelecom of Roshydromet and IRAM. Preliminary verification results were obtained for 2.5 months period from April to June 2018.
- **The analysis and the corresponding adjustment** were made according to the results of the preliminary verification allowed to improve the general accuracy of nowcasts.

Unfortunately for the project, during the spring and the summer 2018 there was the lack of conditions of low clouds and limited visibility, only isolated episodes were noted.

1st IOP – 01.02.2018 – 31.05.2018

The first fog after the Nowcasting System installation (21.02.2018) was predicted with good accuracy, including the visibility value and the time of formation and dissipation of fog. The predicted visibility in the fog was up to 275-300 m, and the actual visibility was between 150 - 250 m.



2st IOP – 01.09.2018 – 31.05.2019

- Forecasters of AMC Pulkovo **were trained** in nowcasting system usage.
- Nowcasts of visibility and ceiling were implemented **in operational practice** and now are regularly used by AMC Pulkovo weather forecasters as advisory for TAF, forecasts for landing and take-off, aerodrome warnings and for the ATC and aerodrome operator pre-operational briefings.

2st IOP – 01.09.2018 – 31.05.2019

- **Verification and analysis** was carried out using the updated nowcasts Verification scheme.
- From September, 2018, verification is regularly carried out. Nowscasts are verified routinely and are available to AMC Pulkovo forecasters through a web site.

- During the period of 10.09-02.11.2018 after some technical and organizational coordination (formats, transfer scheme, etc.) the test was carried out to transfer observation and nowcasting data to **AvRDP project server/site** (via ftp). The transfer was successful and since 01.08.2019 nowcasting data has been transferring to AvRDP ftp server regularly.

- Updating of nowcasting system **using temperature profiler MTP-5** was delayed up to due to some technical problems. MTP-5 is been implemented since May 2019

MET-ATM INTEGRATION

- One of the most challenging tasks of the Pulkovo nowcasting project is the interaction with air traffic services regarding **integration of visibility and ceiling nowcasting into ATM systems** and collection of ATM data to evaluate the impact of nowcasting on the ATM operational activities.
- For that, it is the clear need to prove air navigation that visibility and ceiling nowcasts are **sufficiently reliable for practical use**.
- The presentations and reports about Pulkovo nowcasting project were performed to the North West brunch of State ATM Corporation. The result is the ATM interest.

- At that moment there is **on-going interaction with ATM** for the development of technology for real-time nowcasting data transmission to ATM systems (tentatively for ATM Simulator).
- The themes of discussion:

1. The nowcasts (prognostic values) of visibility and ceiling for the next 60 minutes will be transmitted with 10 minutes time resolution and 10 minutes update period;

2. Data transfer from MeteoExpert nowcasting system will be performed to simulator of the ATM information system “Alpha” in test mode. Such transfer of additional data does not affect the operational work of ATM personal.

VERIFICATION

➢ **The objective for nowcasts verification** is understanding and hence improving the nowcasting system. Verification scheme needs to be customer-oriented and takes into account thresholds that are relevant to different users – meteorological and aviation.

➢ Verification of the LED nowcasting is provided in 2 ways **- objective and subjective:**

✓ subjective verification is based on the opinion of operational forecasters about the performance, effectiveness and usefulness of nowcasts for their daily shifts.

✓ objective verification. Pointed MeteoExpert nowcasts are verified against actual observations at the MET site point (METARs, SPECI and local reports). Verification involves investigation of the properties of joint forecasts and observations distribution for each 10 minutes.

➢ **Verification thresholds** are chosen that are directly relevant to the users. Criteria of accuracy correspond to operationally desirable accuracy of forecasts stated in ICAO Annex 3.

✓ visibility (VIS) are verified under two thresholds (1000m and 3000m) with the accuracy: ±200m for VIS <800 m and ±30 % for VIS >800 m.

✓ ceiling (CEIL) are verified under one threshold (300m), accuracy: ±30m for CEIL<300 m.

VERIFICATION

Verification results are expressed in terms of different **verification measures** - p(e), H, F, PC and other.

- To generate the verification metrics, a set of forecasts is displayed in a 2 x 2 **contingency table** representing the frequencies of forecast–observation pairs for which the event (visibility is equal to or below thresholds) and non-event (visibility is higher than threshold) were forecasted and observed.

- For the verification of rare (extreme) events (such as fogs) Extremal Dependency Index (EDI) and Symmetric Extremal Dependency Index (SEDI) are used as the most informative ones.

n594813_e0301749	Видимость: 3000м	116

Условные обозначения

a	число случаев, когда явление прогнозировалось и
b	число случаев, когда явление прогнозировалось, н
c	число случаев, когда явление не прогнозировалос
d	число случаев, когда явление не прогнозировалос
n = a+b+c+d	общее число прогнозов за заданный период
PC =(a+d)*100/n	оправдываемость прогнозов
PC+ = a*100/(a+b)	оправдываемость прогнозов наличия явления
PC- = d*100/(c+d)	оправдываемость прогнозов отсутствия явления
P+ = a*100/(a+c)	предупрежденность прогнозов наличия явления
P- = d*100/(b+d)	предупрежденность прогнозов отсутствия явлени

Станция	Параметр	H
n594813_e0301749	Видимость: 3000м	0.67

Условные обозначения

H = a/(a+c)
F = b/(b+d)
FAR = b/(a+b)
Miss = c/(c+d)
ORSS = (a*d-b*c)/(a*d+b*c)
EDI = (log(F)-log(H)) / (log(F)+log(H))
SEDI = (log(F)-log(H)-log(1-F)+log(1-H)) / (log(F)+log(H)+log(1-F)+log(1-H))
p(e) = (a+c)/n
prec_fcst
lead_time

VERIFICATION

- Nowscasts are verified routinely and are available for Pulkovo forecasters via web site.
- It is possible to select verification results for any period of time from one day to several months.
- Online forecast verification appears to be a useful tool to the forecasters so they can easily analyze in real time the accuracy of nowcasts produced by the system.

Карта | Метео | Профиль температуры | Верификация прогнозов | Помощь | pulkovo_nowcasting | Выйти

Метеоэксперт: верификация прогнозов

n594813_e0301749, | Видимость: 3000м | 06.09.2018 | 06.03.2019 | Считать

Результаты оценки точности прогнозов опасных явлений на 4 часа

рассчитываемый период: с 06-09-2018 00:00 по 06-03-2019 23:59

Станция: n594813_e0301749,

Параметр: Видимость: 3000м

a	b	c	d	n	PC(%)	PC+(%)	PC-(%)	P+(%)	P-(%)	H	F	FAR	Miss	ORSS	EDI	SEDI	p(e)	prcs(мин)	adv(мин)
14544	13180	1913	177776	207413	93	52	99	88	93	0.88	0.07	0.48	0.01	0.98	0.91	0.92	0.08	126	225

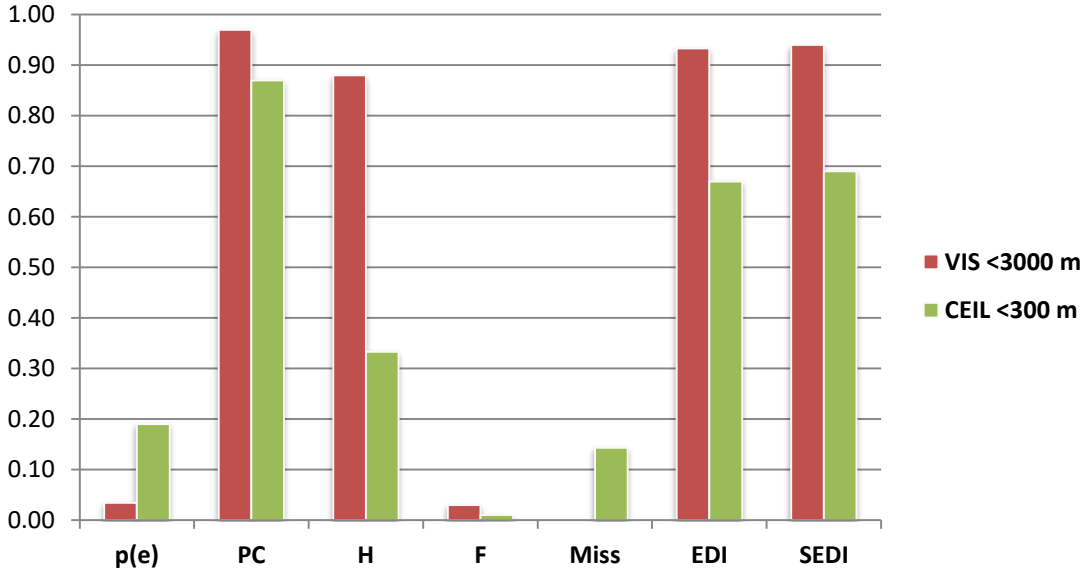
Условные обозначения

a	число случаев, когда явление прогнозировалось и наблюдалось
b	число случаев, когда явление прогнозировалось, но не наблюдалось
c	число случаев, когда явление не прогнозировалось, но наблюдалось
d	число случаев, когда явление не прогнозировалось и не наблюдалось

VERIFICATION

According to the results of verification, for the period of September 2018 – May 2019, the work of nowcasting system is seen to be satisfactory and the verification results are as follows:

- ✓ Probability of event (visibility less than 3000 m) – 0.03, H (hit rate) – 0.88, F (false alarm rate) – 0.03, total accuracy PC (proportion of correct forecasts taking into account the forecast of non-event) – 0.97
- ✓ Probability of ceiling less than 300 m – 0.19, H (hit rate) – 0.34, F (false alarm rate) – 0.01, total accuracy PC (proportion of correct forecasts taking into account the forecast of non-event) – 0.87



CASE STUDY

2-3 June 2018

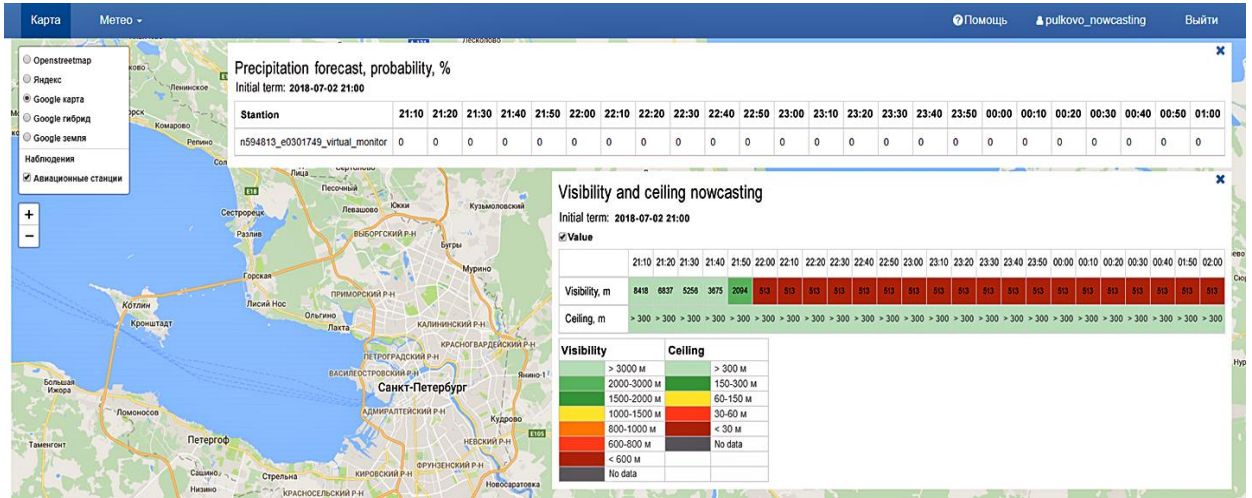
➢ According to the synoptic analysis, on July 02 the situation in the St. Petersburg area was influenced by the cyclone trough with its center in the west of the region.

➢ This process was not well-anticipated by forecaster. The fog and low clouds were expected by forecaster only from 00 till 03 UTC with the visibility decreasing only down to 1000m.

TAF ULLI *021958Z 0221/0321 15003MPS 4000 -RA BR BKN005 BKN015 TEMPO 0221/0224 11003MPS 2100 -SHRA BR BKN003 BKN017CB TEMPO 0300/0303 20003MPS* ***1000 -SHRA BR*** *BKN002 BKN011CB …=*

➢ At 21:00 UTC nowcasting system started to expect fog the aerodrome from 22 till 02 UTC with the range of 500 m.

➢Actually fog was observed **from 22.55 till 04.12 UTC**



CASE STUDY

5 September 2018

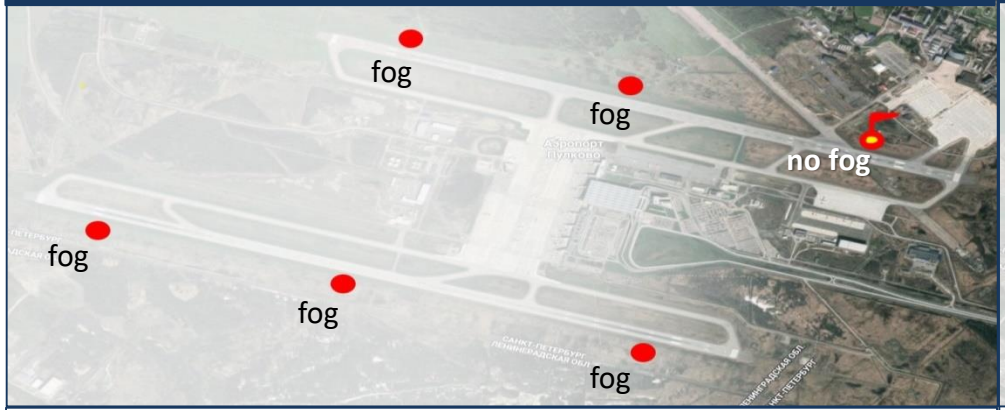
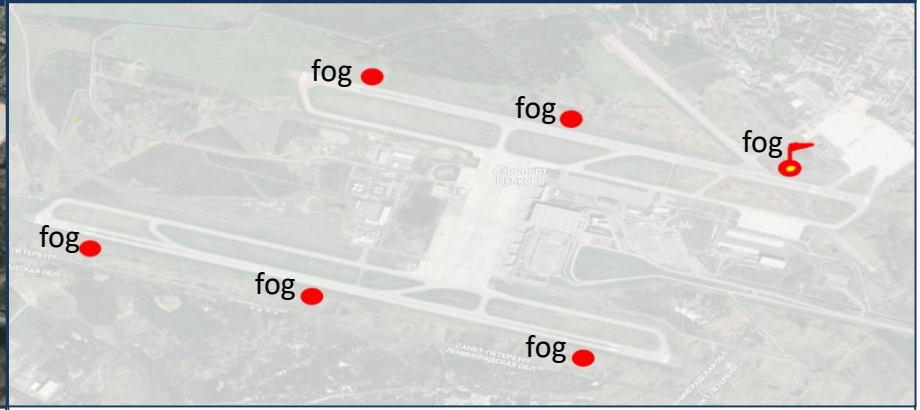
- At 19:00 UTC in the area of RWY 28R, visibility more than 3000m was observed.
- For the MET site point nowcasting system did not predict any fog and that was a correct forecast.
- The forecaster expected only the temporal decreasing of visibility and ceiling at the period 21 – 06 UTC

TAF ULLI 051656Z 0518/0618 17003MPS 4000 BR SCT011 BKN017 TEMPO 0518/0521 22003MPS 3100 -SHRA BR BKN011 BKN017CB TEMPO 0521/0606 VRB01MPS ***0700 FG VV003 … =***

But from 19.21 UTC fog started to be observed over aerodrome but again not at Met Site.

METAR *ULLI 051900Z 00000MPS 6000 NSC 18/17 Q1020 NOSIG*
SPECI *ULLI 051921Z 00000MPS 2200 0900SW PRFG BR NSC 18/17 Q1020 NOSIG*
SPECI *ULLI 051927Z 00000MPS 1300 0900NW R10L/1400D PRFG BR NSC 18/17 Q1020 NOSIG*
METAR ULLI 051930Z 00000MPS 1200 0250SE R10L/P2000U PRFG BR NSC 17/16 Q1020 NOSIG

METAR ULLI 051930Z 00000MPS 1200 0250SE R10L/P2000U
PRFG BR NSC 17/16 Q1020 NOSIG

19:03 – 23:40 UTC	From 23:50 UTC
	
Nowcast: no fog at the flagged point (RWY 28R), ***Observation***: no fog (VIS > 3000 m) at the MET point and fog at 5 other points => forecast is correct	***Nowcast:*** fog from 23.50. ***Observation:*** fog was at the flagged point => forecast is correct

METAR ULLI 060000Z 00000MPS 0250 0150NW R28R/0550N FG
BKN001 15/14 Q1020 NOSIG

Summary

- **Benefits to aviation/ATM**
  - ✓ more accurate TAF and TREND forecasts
  - ✓airport capacity improvement
  - ✓ATM procedures optimization

- **Gap identified**
  - ✓ nowcasts lead time is not satisfactory
  - ✓ nowcasting for different sites at the aerodrome is required

- **Future Plans**
  - ✓ to continue interaction with ATM department regarding identifying of benefits and requirements of nowcasting integration into ATM systems
  - ✓to implement nowcasting of visibility and ceiling at another aerodromes (Novosibirsk)
  - ✓to try to nowcast convection (thunderstorm, precipitation) for South territories of Russia


Iqaluit
Toronto
St. Petersburg
Paris
Shanghai
Tokyo
New Delhi
Hong Kong
Singapore
Johannesburg

THANK YOU!