World Meteorological Organization **AvRDP/5/Doc.06**

COMMISSION FOR ATMOSPHERIC SCIENCE/WWRP &
COMMISSION FOR AERONAUTICAL METEOROLOGY 19.08.2019

Concluding Meeting of AvRDP/SSC and Aviation Seminar
Johannesburg, South Africa
19 - 22 August 2019

FINAL REPORT OF PULKOVO (LED) AIRPORT

(Submitted by Larisa Nikitina)

Summary

An additional equipment (AWS Station and Temperature Profiler) was installed at the meteorological observational site of Pulkovo (Saint-Petersburg) aerodrome for Nowcasting Project purposes. «MeteoExpert» Nowcasting System was installed in order to produce visibility, ceiling and precipitation forecasts 4h ahead with 10-min temporal resolution and 10-min updates. The System put into operational use (for operational forecasters via specialized website) since February 2018. Verification scheme of nowcasting was developed and put into force since September 2018. An interaction with ATM department regarding identifying of benefits and requirements of nowcasting integration into ATM systems (preliminary to ATM Simulator) is still the main gap and is on-going process. New MET information about high impact weather (low visibility, low ceiling) can be transmitted in real-time into the ATM systems (tentatively for ATM Simulator) for decision-making

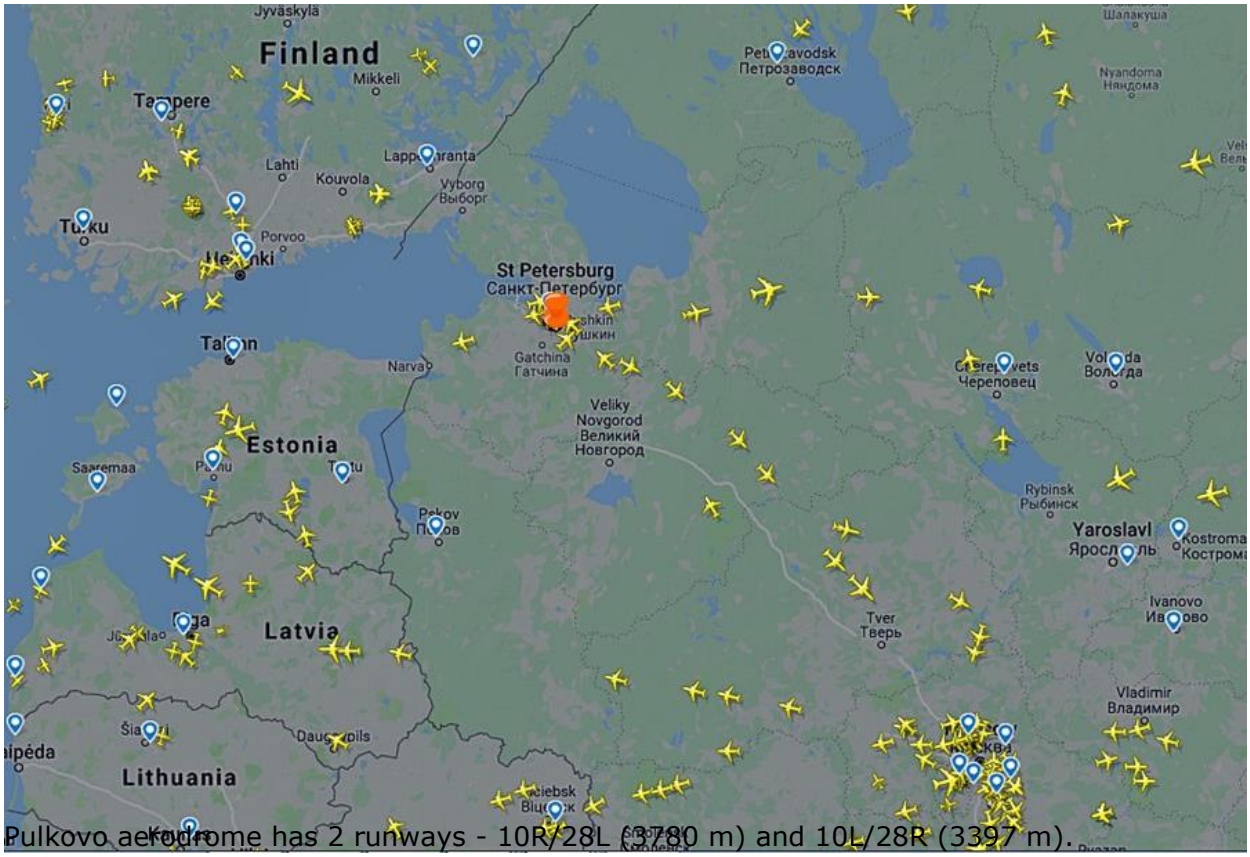
I. Introduction

(1) Airport information

Pulkovo airport (St. Petersburg, Russia) 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).

The 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;
- between 2 big water reservoirs (10 km East from the Gulf of Finland and 50 km West from Ladoga Lake);
- above 24 m MSL.



Pulkovo aerodrome has 2 runways - 10R/28L (3780 m) and 10L/28R (3397 m).

(2) Impacting weather

Pulkovo aerodrome (LED) is located in the transitional zone from the sea climate to continental climate and is characterized by a high frequency of Atlantic air masses passing. Cyclonic weather processes increase in the cold period of the year and weaken in the warm

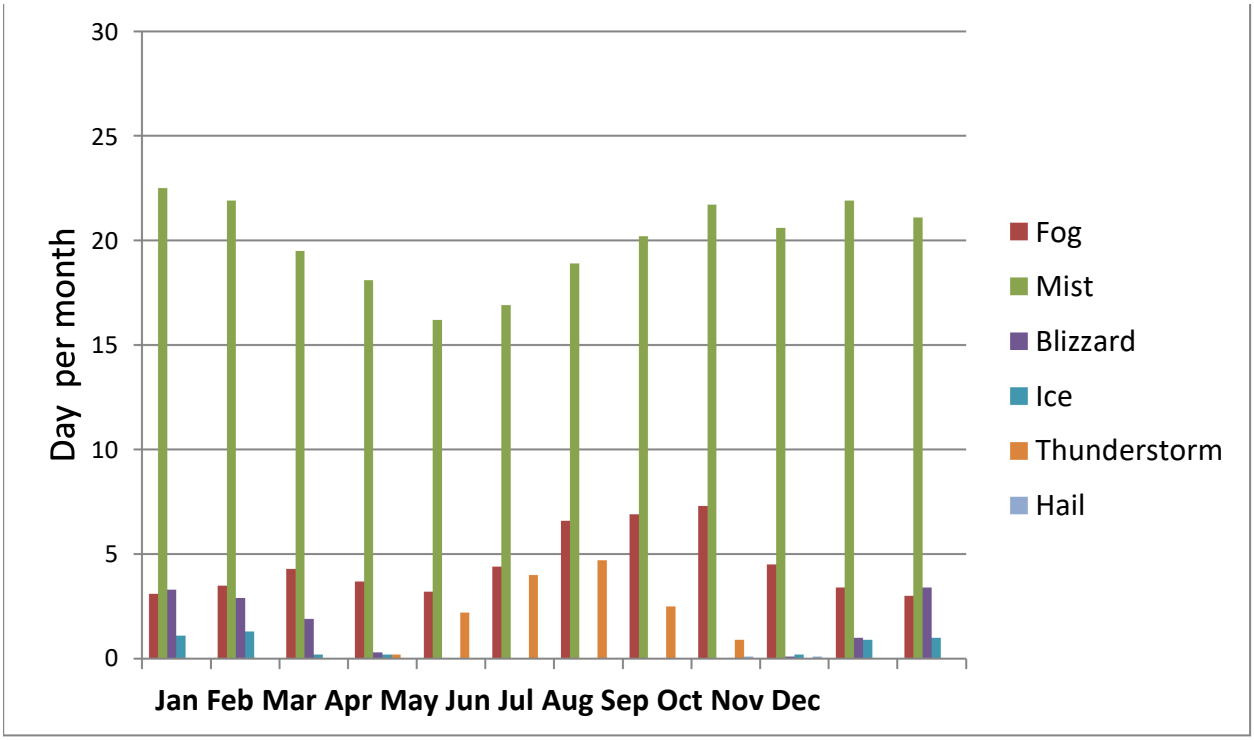
period, as a rule. Active cyclones and frequent changes of air masses determine the unstable nature of Pulkovo weather in all seasons.

The brief climatology of LED for the different weather phenomena:

- 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).

The airdrome operations and air traffic at Pulkovo are mainly impacted by the low visibility (caused by mists and fogs) and ceiling, by heavy snow and blizzards in winter time. 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 airdrome operations and air traffic.

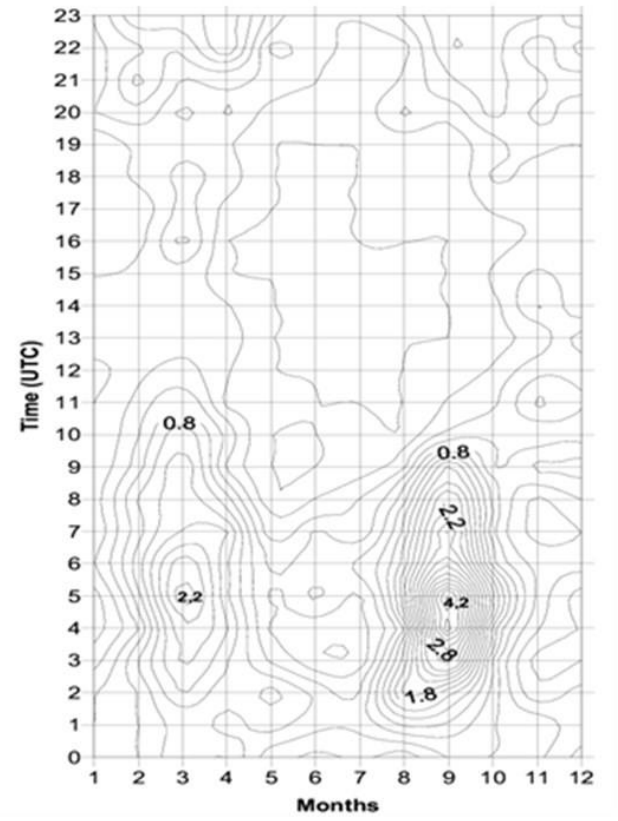


The given weather phenomena, especially fog, significantly impact on aviation in winter time:

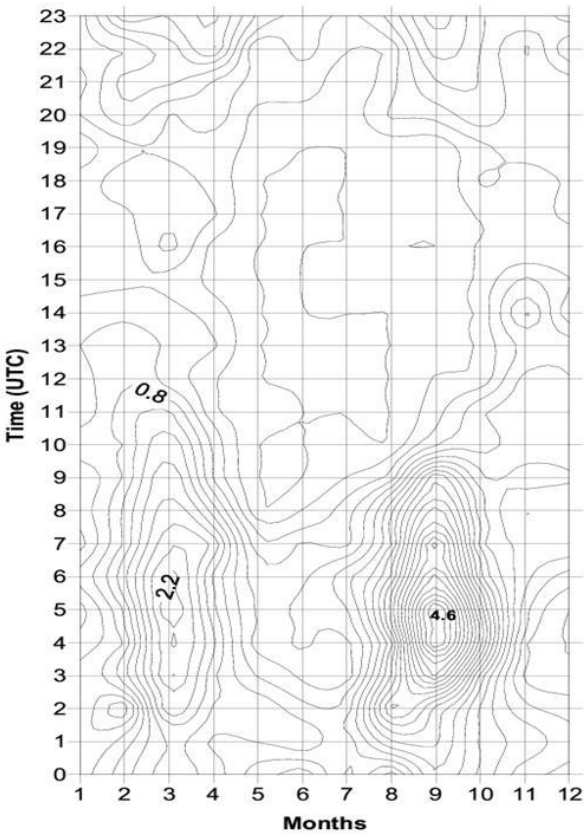
- Heavy snow and blizzards with visibility decrease less than 1000 m and wind intensification (more than 15 m/s) are observed in January-February, and are associated mainly with the southern cyclones;
- Most often, blizzards duration is 12 h or less. The longest snowstorm was observed in November - 22 h.
- The greatest number of days with fog is in September-October. The longest fogs (up to 18-20 h) are observed in March during the active snowmelt;
- Duration of weather conditions RVR <350 m and/or ceiling <30 m is 1 hour or less but there are some cases when duration are 18-24 hours (0.1% of the total number of observations).

The adverse weather conditions with the low clouds and visibility are mostly observed in March, September and December at night time and in the morning.

Daily-annual variation rate of the combination:



RVR <350 m and/or Ceiling <30 m



RVR <800 m and/or Ceiling <60 m

(3) ATM/Airline/Pilot/Aviation Community Needs

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. Generation of accurate and timely nowcast products is a basis of early warning automated system providing information about significant weather conditions (fog, low visibility, low clouds, heavy precipitation …) for decision-makers.

Based on the analysis of the LED climatology and influence of meteorological conditions on the regularity of the aerodrome operational activities, it was decided to develop and implement nowcasting of visibility range and ceiling.

The major goals of Pulkovo aviation weather nowcasting project are as follows:

1. to improve the quality of TAF/GAMET and regular pre-operating weather briefings to ATM and aerodrome operator (especially the forecasts of phenomena associated with the deterioration of visibility and lowering of clouds) and,
2. 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;
- To deliver nowcasts to the aviation weather forecasters in real time;
- To improve visibility and ceiling forecasts at aerodrome;
- To assess benefits of forecast improvement (verification).

(4) Study approach / techniques

Visibility and ceiling nowcasting system was developed as an 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 Olympics in Sochi and showed consistently positive results. In addition, since 2015 such nowcasting system has been operating at the Irkutsk airport as a research polygon.

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

Data sources for nowcasting system:

- Aviation weather observation station (AWOS, every 1 min) - 6 visibility sensors and 4 ceiling sensors, obtained with the help of the automated meteorological measuring system KRAMS-4;
- Additional sensors of the AWS «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 at a depth of 120 cm), observations every 10 min;
- Atmosphere sounding data (by the aerological station Voeikovo, twice a day) and AMDAR;
- Pulkovo Doppler radar data and Roshydromet Radar network (every 10 min);
- Temperature profiler MTP-5 (every 5 min, implemented on May 2019).

	Observations								Models/nowcasting			ATM Data				
	RADAR	Satellite	AWOS	Temperature profiler MTP-5	Wind Profiler	Lidar	AMDAR	Other	Nowcasting	Mesoscale NWP	Reginal model	AIREP	Air traffic data	Airport capacity	ATM data	Other
D	√	√	√	√	-	-	√	√	√	√	√	√	-	-	-	-

Model

The 1D ABL model based on the system of hydrodynamics prognostic equations of the horizontally homogeneous boundary layer of the atmosphere 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 GRIB-coded data from NWP model.
- Data of observations are used to set as initial conditions.

At the stage of initialization of the model, the Monin-Obukhov similarity theory for the surface layer and parametrization for the upper part of the ABL are involved.

Prognostic variables: vertical profiles of wind speed and direction, 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 value.

- 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 climatic data of the aerodrome.
- 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.

The model description is presented in the publication: T. A. Bazlova, N. V. Bocharnikov. Verification of the MeteoExpert Nowcasts. Universal Journal of Geoscience 2017, Vol. 5 (1), pp. 1 - 9, DOI: 10.13189 / ujg.2017.050101 and others.

The results of using the model in the nowcasting system were presented at conferences and meetings: 1st European Nowcasting Conference (ENC2014), EMS-ECAM-2015, ICAO METG PT EAST-2014 (2015), WMO CAeM-ET-CCP-1, WMO AMSC-2017 and others

System utilizes the latest observation data and updates every 10 minutes, vertical resolution is much higher in the lowest surface layers, 75 vertical levels.

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 1D numerical model of the atmospheric boundary layer for points, visualisation, and recording of results;
- Database for data storage;
- Specialised Web-site for data visualization.

(5) Timeline

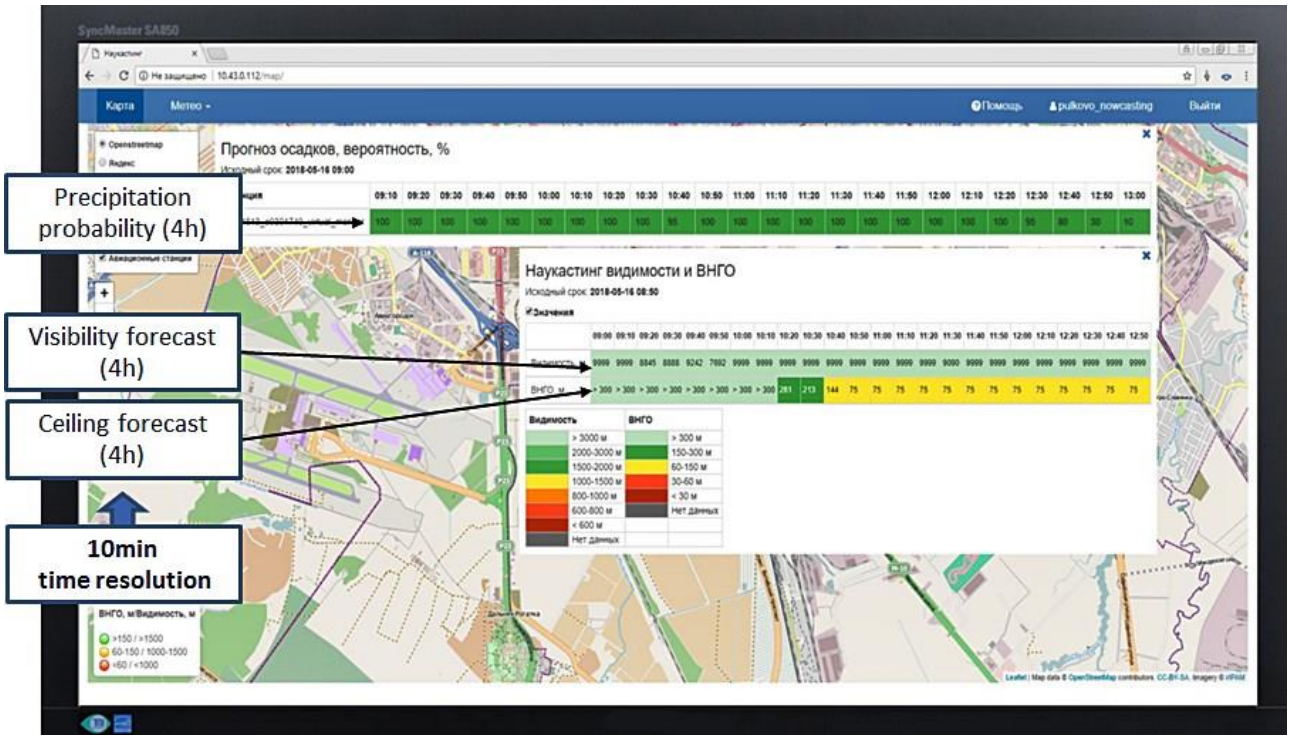
Nowcasting system of visibility and ceiling has being implemented at the Pulkovo AMC (Aviation Meteorological Center) (Aviamettelecom of Roshydromet, North-West branch) since February 2018 in 24/7 automatic mode.

The assimilation of new observational data and recalculation are carried out every 10 min. Nowcasts of the following most critical parameters with lead time of 4h at 10-min intervals, updated every 10 minutes:

- Visibility (with the emphasis on Vis<1000m);
- Ceiling
- Precipitation

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.



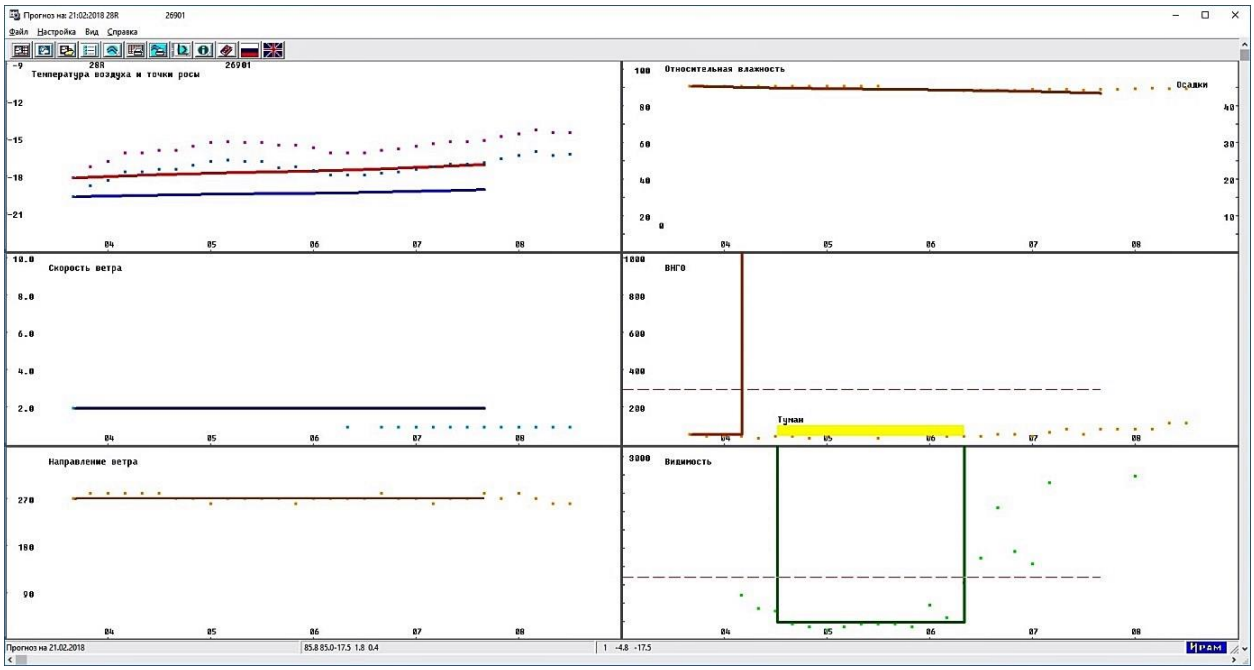
II. Outcomes

(1) Phase I achievements (MET Capability)

1st IOP - 01.02.18 – 31.05.18

1. Basic nowcasting system is developed for the data from one point of aerodrome (meteorological observational site with an additional AWS station – MET site).
2. 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.
3. 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.
4. 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.

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.



2nd IOP 01.09.2018 – 31.05.2019

5. Forecasters of AMC Pulkovo were trained in nowcasting system usage.
6. Nowcasts of visibility and ceiling were implemented in operational practice and 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.
7. The development of advanced nowcasting scheme using temperature profiler MTP-5 was delayed up to May 2019 due to some technical problems.
8. Verification and analysis was carried out using the updated nowcasts Verification scheme.
9. From September, 2018, verification is regularly carried out (taking into account the threshold criteria of 3000 m and 1000 m for visibility and 300 m for the ceiling). Nowscasts are verified routinely and are available to the AMC Pulkovo forecasters through a web site.
10. During the period of 10.09.2018 - 02.11.2018 the test to transfer observation and nowcasting data to AvRDP project server/site (via ftp) after some technical and organizational coordination (formats, transfer scheme, etc.) was carried out. The transfer was successful and since 01.08.2019 nowcasting data has been transferring to AvRDP server regularly.

(2) Phase II achievements (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 was the 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 a resolution of 10 minutes and an update period of 10 minutes;

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

(3) Verification

The objective for the 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 formats - 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 weather forecasts produced by MeteoExpert is verified against actual observations at the MET site (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.

a. Visibility (VIS) are verified under two thresholds (1000m and 3000m) with the accuracy: ±200m for VIS <800 m and ±30 % for VIS >800 m.
b. Ceiling (CEIL) are verified under one threshold (300m), accuracy: ±30m for CEL<300 m.

Verification results are expressed in terms of different verification measures - p(e), H, F, FAR, Miss, PC, ORSS, EDI and SEDI derived from the contingency table. 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 nonevent (visibility is higher than threshold) were forecasted and observed.

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 of rare (extreme) events such as fogs is difficult task because of degenerating of traditional forecast performance measures to trivial values (zero or infinity). Two measures - Extremal Dependency Index (EDI) and Symmetric Extremal Dependency Index (SEDI) were shown to overcome all these shortcomings as they are base-rate independent and no degenerating measures and it was decided to use EDI and SEDI for the nowcasts verification as the most informative ones.

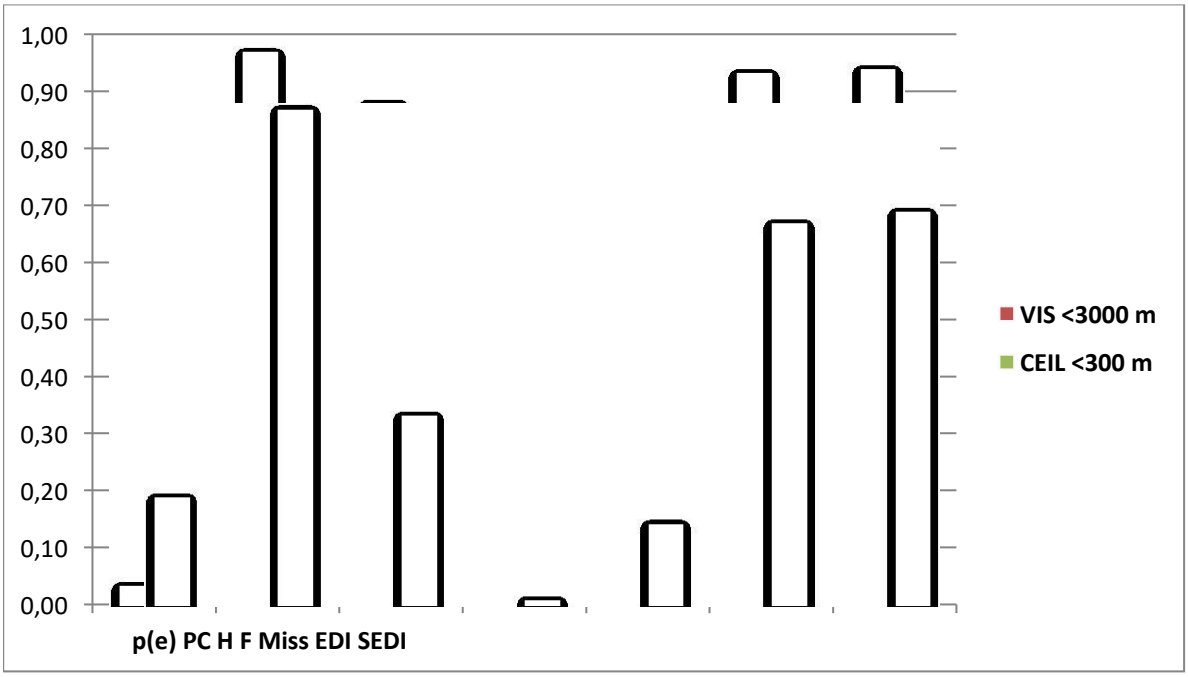
Nowscasts are verified routinely and are available for the AMC Pulkovo forecasters through a web site. It is possible to select a verification period from one day to several months for any period of time. Online forecast verification appears to be a useful tool to the forecasters so they can easily analyze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

Regular analysis of nowcasts verification results are provided to IRAM in order improve the nowcasting system.

According to the results of verification, for the period of June 2018 – July 2019, the work of nowcasting system is satisfactory and the verification results are as follows:

• Probability of event (visibility less than 3000 m) – 3%, H (hit rate) - 88%, F (false alarm rate) - 3%, the total accuracy PC (proportion of correct forecasts taking into account the forecast of nonevent) – 97%;
• Probability of ceiling less than 300 m - 19%, H (hit rate) - 34%, F (false alarm rate) - 1%, the total accuracy PC (proportion of correct forecasts taking into account the forecast of nonevent) - 87%.

Visibility and ceiling nowcasts verification for the operation period 2018.06 – 2019.07



(4) Case studies

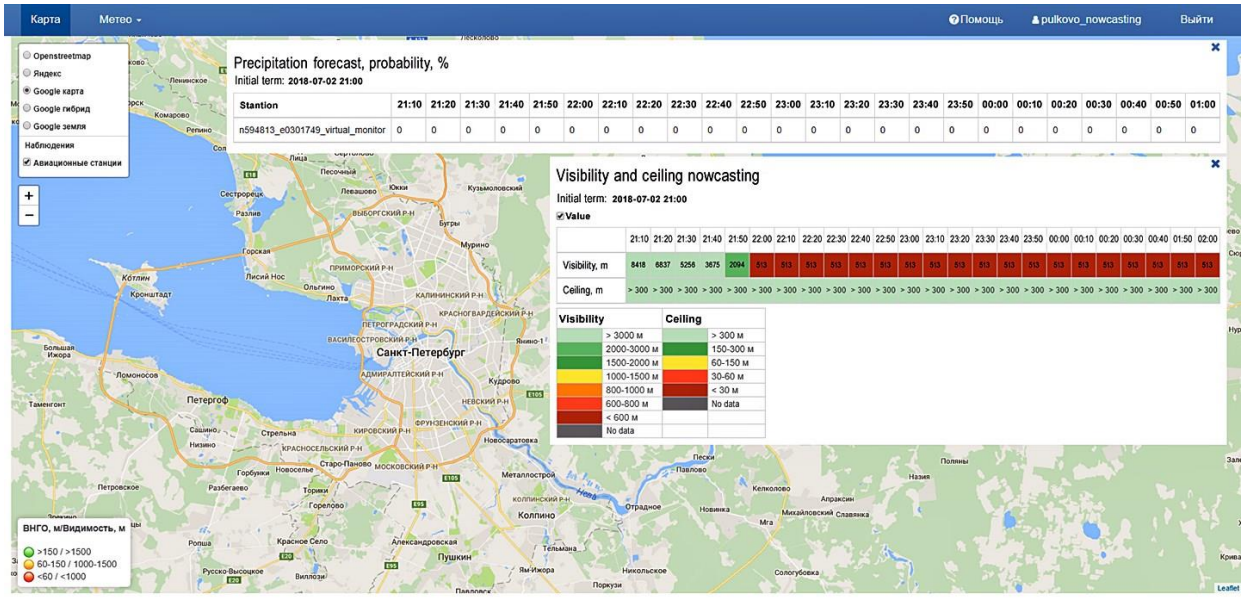
According to the synoptic analysis, on July 02, synoptic situation in the St. Petersburg area was influenced by the cyclone trough with its center in the Belarus region.

- The leading stream direction (AT-700 hPa) over the area of the Pulkovo was from the South East with the speed about 80-100 km / h.
- No inversion was observed from 00 to 04 BCB on July 3, 2018 according to the temperature profile data.
- Considerable Stratiform cloudiness and masked Cumulo clouds were observed in the vicinity of St. Petersburg by radar data.
- Based on the analysis of NWP from 00 utc and 06 utc, further northward cloud shift was expected with some light precipitation and low (30%) probability of thunderstorm.

This process was not well-anticipated by forecaster. The fog and low clouds were expected by forecaster only from 00 utc till 03 utc with the visibility deterioration down only 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 …=*

According to nowcasting system data, fog was expected at the airport from 22 utc till 02 utc with the range of 500 m.



Actually fog was observed from 22.55 utc till 04.12 utc.

METAR *ULLI 022230Z 15001MPS 9999 OVC032 12/11 Q1010 R28L/290050 NOSIG*
SPECI *ULLI 022255Z 12002MPS 1500 0550SE R28L/0750D PRFG BR FEW001 BKN023 12/11 Q1010 R28L/290050 NOSIG*
METAR *ULLI 022300Z 11002MPS 1900 0350SE R28L/0800D PRFG BR FEW001 BKN023 11/10 Q1010 R28L/290050 TEMPO 0300 FG VV002*
SPECI *ULLI 022311Z 15002MPS 0550 0350SW R10R/2000D FG FEW002 10/09 Q1010 R10R/290050 TEMPO 0300 FG VV002*
…
SPECI *ULLI 030351Z VRB01MPS 0350 0250E R10L/0350N FG VV001 11/10 Q1009 R10L/290050 NOSIG*
METAR *ULLI 030400Z VRB01MPS 1100 0400NW R10L/0450U PRFG BKN001 11/10 Q1009 R10L/290050 NOSIG*
SPECI *ULLI 030419Z 12003MPS 090V150 5000 BR SCT001 11/11 Q1009 R10L/290050 NOSIG*
METAR *ULLI 030430Z 10002MPS 040V150 9000 SCT001 12/11 Q1009 R10L/290050 NOSIG*

This case illustrates the satisfactory correctness of nowcasts and the possible positive impact of using nowcasting data by the forecaster.

Fog Case, September 5, 2018

In the period from 19:03 to 23:40 in the area of RWY 28R, visibility more than 3000m was observed, for the MET site point the 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

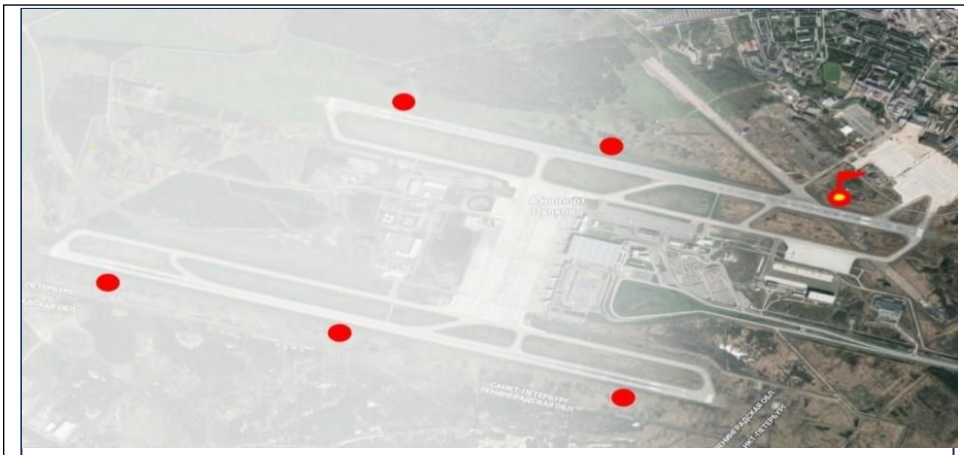
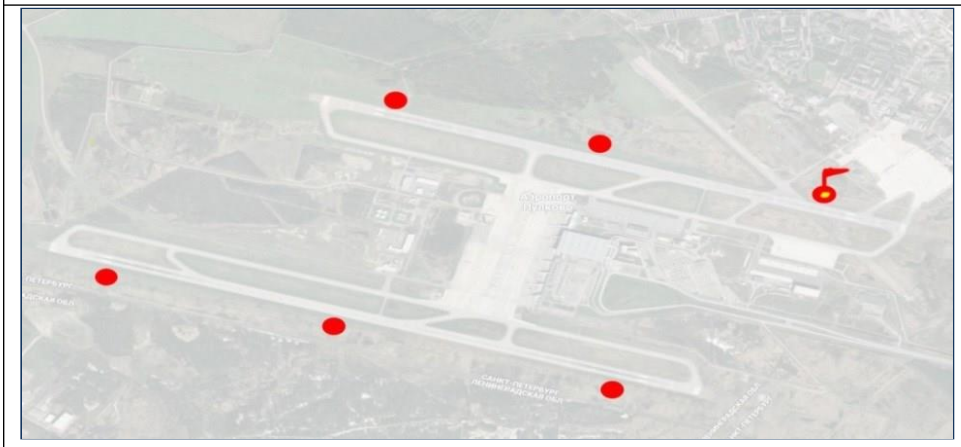
TAF ULLI 051656Z 0518/0618 17003MPS 4000 BR SCT011 BKN017 TEMPO 0518/0521 22003MPS 3100 -SHRA BR BKN011 BKN017CB TEMPO 0521/0606 VRB01MPS ***0700 FG VV003 … =***

At the same time, from 19 utc fog was observed at other visibility sensors.

METAR *ULLI 051900Z 00000MPS 6000 NSC 18/17 Q1020 R10L/090060 NOSIG*
SPECI *ULLI 051921Z 00000MPS 2200 0900SW PRFG BR NSC 18/17 Q1020 R10L/090060 NOSIG*
SPECI *ULLI 051927Z 00000MPS 1300 0900NW R10L/1400D PRFG BR NSC 18/17 Q1020 R10L/090060 NOSIG*

METAR ULLI 051930Z 00000MPS 1200 0250SE R10L/P2000U PRFG BR NSC 17/16 Q1020 R10L/090060 NOSIG
***SPECI** ULLI 051932Z 00000MPS 0450 0250SE R10L/1100D FG NSC 17/16 Q1020 R10L/090060 NOSIG*
…
***METAR** ULLI 060630Z 29001MPS 2100 0250W PRFG BR BKN001 16/16 Q1020 R28R/090060 NOSIG*
***SPECI** ULLI 060631Z VRB01MPS 1400 0250W PRFG BR BKN001 16/16 Q1020 R28R/090060 NOSIG*
***SPECI** ULLI 060643Z 00000MPS 3400 1200W BR BKN002 17/16 Q1020 R28R/090060 NOSIG*

Later, at 22.50, nowcasting System began to predict fog from 23 utc and fog formed at the RWY28R area (and MET site) 1 hour later at 23.50 and it lasted until the next morning.

 ***METAR ULLI 051930Z 00000MPS 1200 0250SE R10L/P2000U PRFG BR NSC 17/16 Q1020 R10L/090060 NOSIG***	**Nowcast:** 19-23 utc no fog at the MET site (RWY 28R, flagged point) **Observation:** no fog (VIS > 3000 m) at the MET site and fog at 5 other points *Nowcast (no fog) is correct*
 ***METAR ULLI 060000Z 00000MPS 0250 0150NW R28R/0550N FG BKN001 15/14 Q1020 R28R/090060 NOSIG RMK QBB030 OBST OBSC***	**Nowcast:** fog from 23.50 utc **Observation:** fog at all sites *Nowcast of visibility is correct*

Nowcast System correctly made forecasts of the fog in terms of its absence and further formation in the vicinity of RWY 28R. However, for the weather forecaster such situation has much uncertainty.

This case study demonstrates an importance to have visibility nowcasts for the different aerodrome points, especially in inhomogeneous visibility conditions

III. Summary

(1) Benefits to local ATM

- more accurate TAF and TREND forecasts
- airport capacity improvement
- ATM procedures optimization

(2) Gap identified

- nowcasts lead time is not satisfactory
- nowcasting for different sites at the aerodrome is required

(3) 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 (precipitation) for South territories of Russia

IV. References

1. T. Bazlova, N. Bocharnikov, A. Solonin. Operational nowcasting systems in the framework of the 4-D MeteoCube. Aeronautical Meteorology Scientific Conference WMO (AeroMetSci2017), Toulouse, France, 6-10 November 2017. https://www.wmo.int/.../Presentation Bazlova_Session1_AeroMetSci-2017.pdf

2. T. A. Bazlova, N. V. Bocharnikov. Verification of the MeteoExpert Nowcasts. Universal Journal of Geoscience 2017, Vol. 5 (1), pp. 1 - 9, DOI: 10.13189 / ujg.2017.050101

3. T. Bazlova, N. Bocharnikov, A. Solonin. Aviation operational nowcasting systems. 3rd European Nowcasting Conference (ENC2019). 24-26 April 2019, Madrid, Spain, https://enc2019.aemet.es/wp-content/uploads/2019/05/ENC2019_BOOK-OF-ABSTRACTS.pdf.

4. A. Korchagin. Pilot projects for aeronautical meteorology in the Russian Federation, Meteorological Technology World Expo, 2019, https://www.ukintpress-conferences.com/proceedings/download.php?uid=391