

# Aviation operational nowcasting systems



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# Background

- 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.



# 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**

### **Cloud ceiling**

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

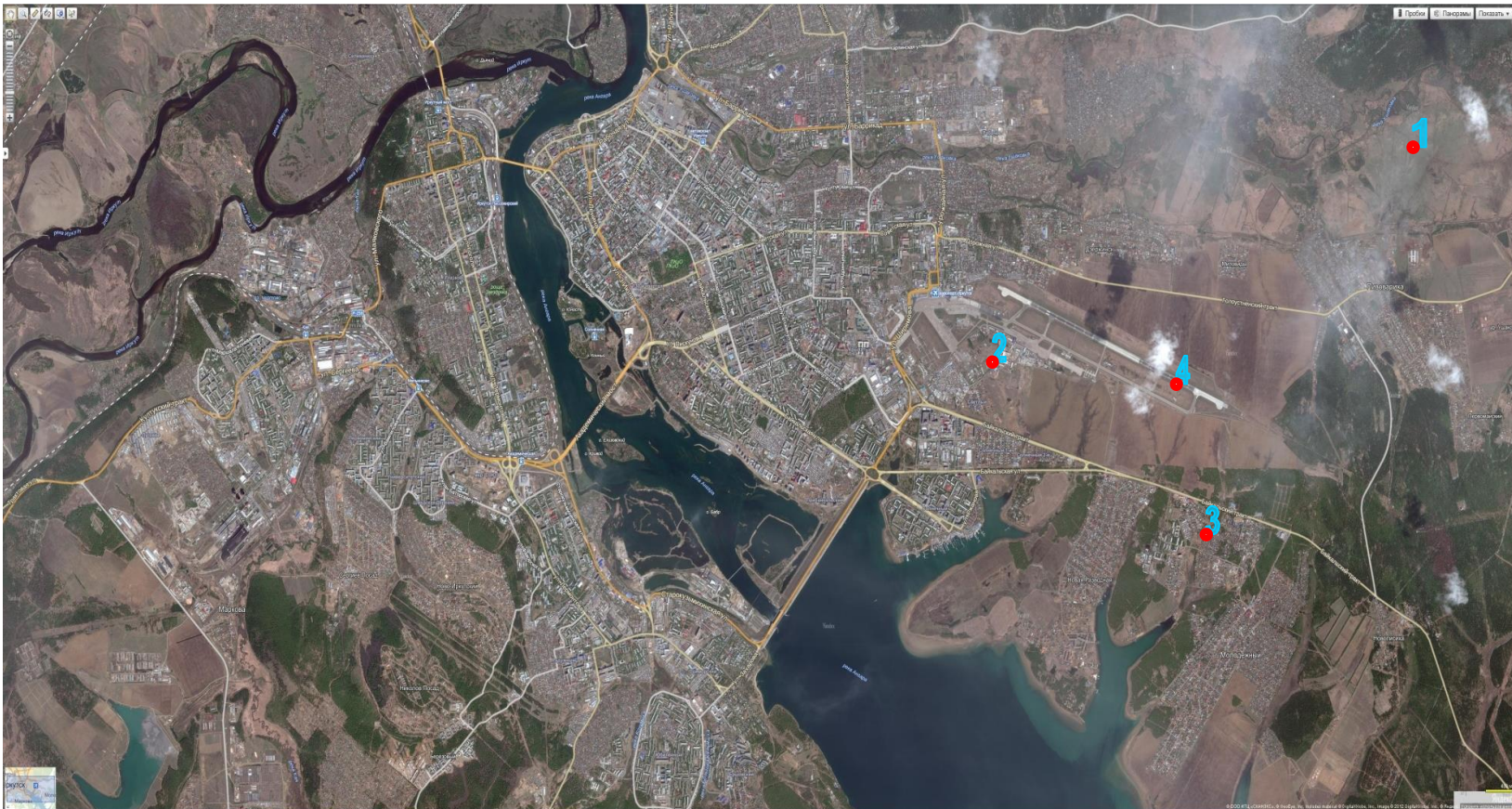
### **Surface T and state**

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**



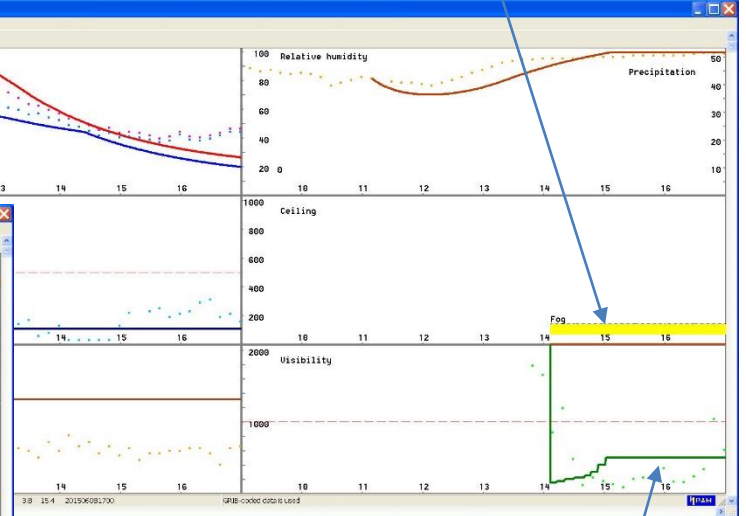
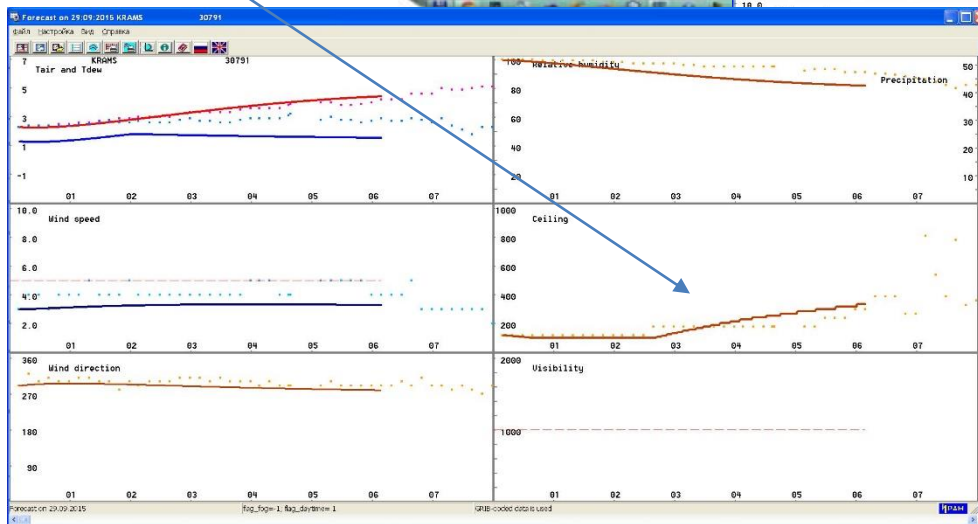
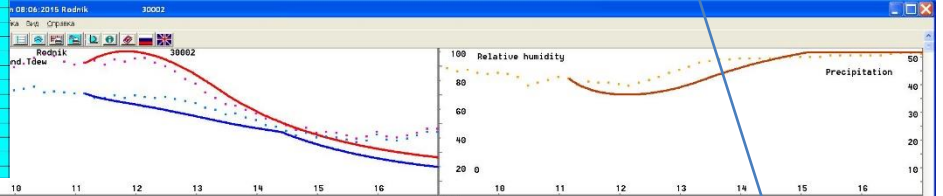
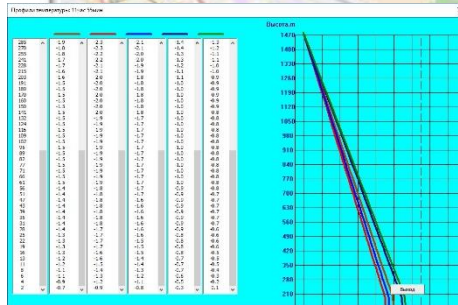
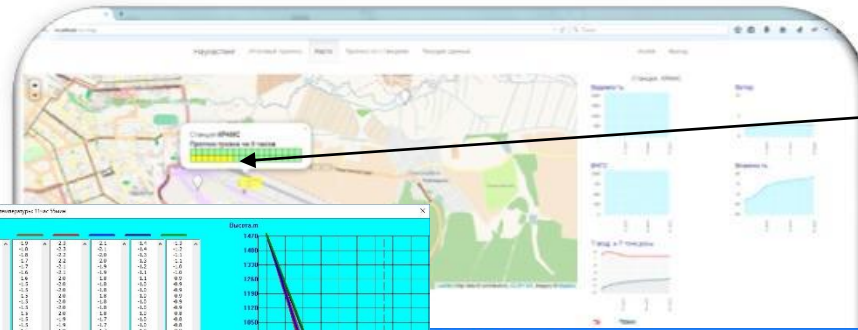
# Tabular, graph and map data displays on workstation and the website

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.**

The screenshot shows a web browser window with the URL `meteoCube.ru/map/#`. The page features a satellite map of the Pulkovo Airport area in Saint-Petersburg, Russia. A legend on the left side of the map includes options for map styles (Openstreetmap, Google карта, Google гибрид, Google земля) and weather observation types (Аэропорты, Радиолокация, Явления погоды). A weather data panel on the right side of the map displays the following information:

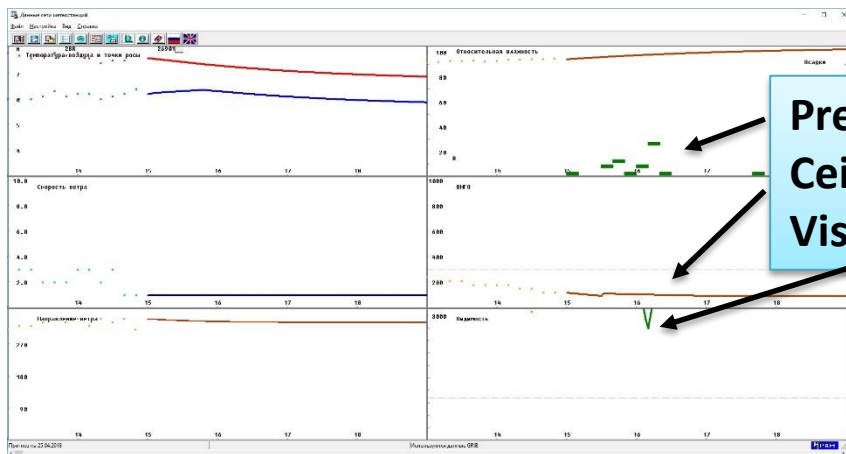
Наукастинг	
Исходный срок:	20
Значения	
	11:
Видимость, м	
ВНГО, м	

Below the table, there is a color-coded bar for visibility and ceiling (ВНГО, м) with segments in yellow and green.

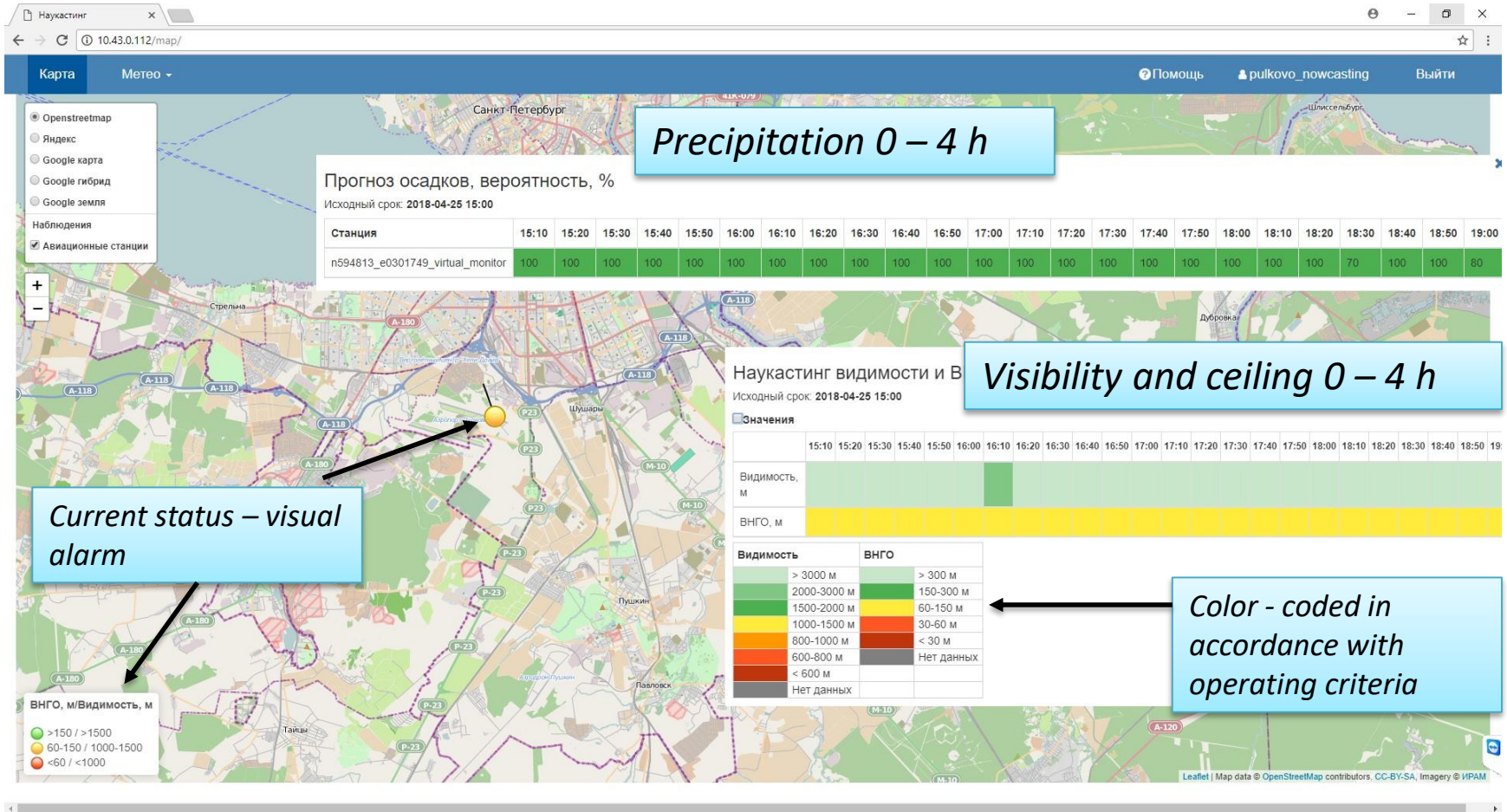


Observations and forecasts are visualized on screens of workstations and the MeteoCube website

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



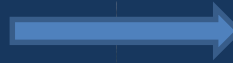
# Precipitation, low ceiling and visibility



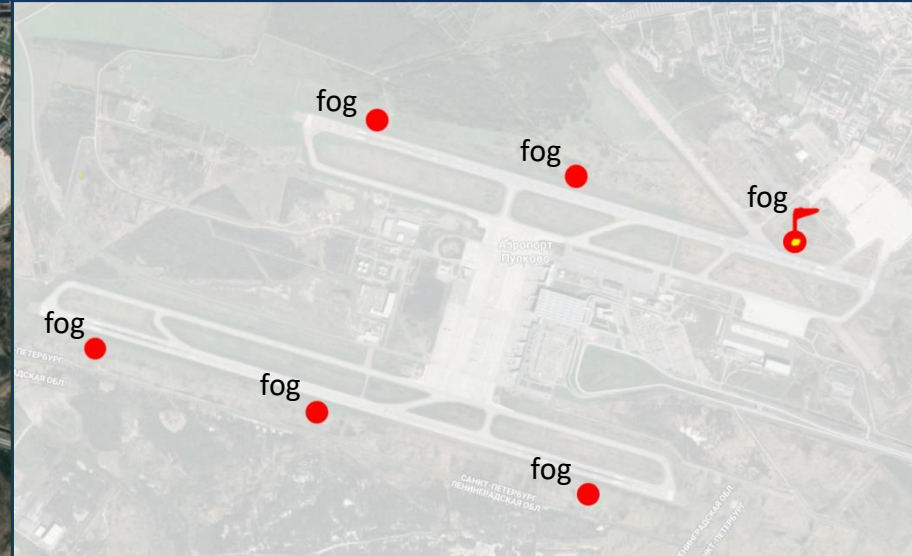
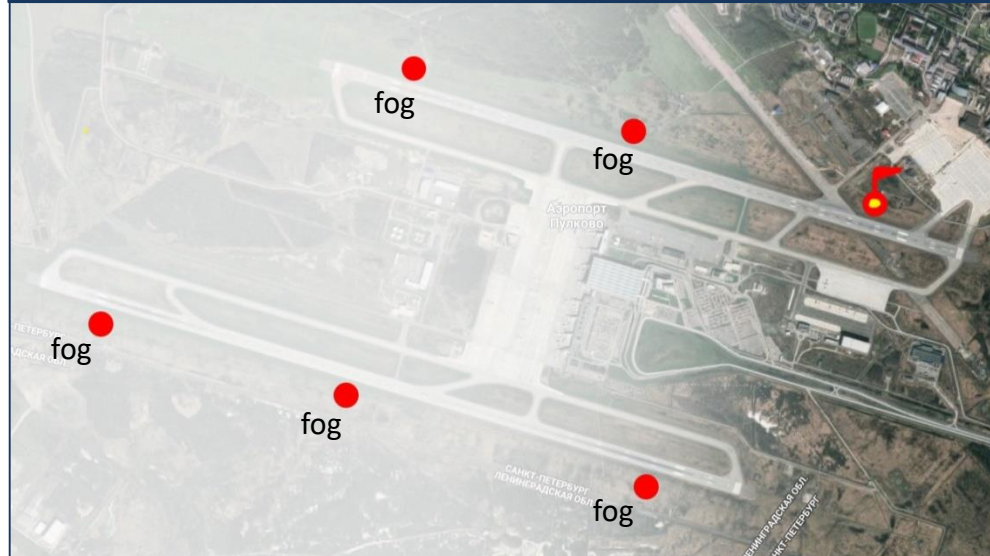


**Case study (fog, 05.09.2018, Pulkovo) demonstrates an importance to have correct visibility forecasts for different aerodrome points, especially in inhomogeneous visibility conditions**

19:03 – 23:40 UTC



23:50 UTC



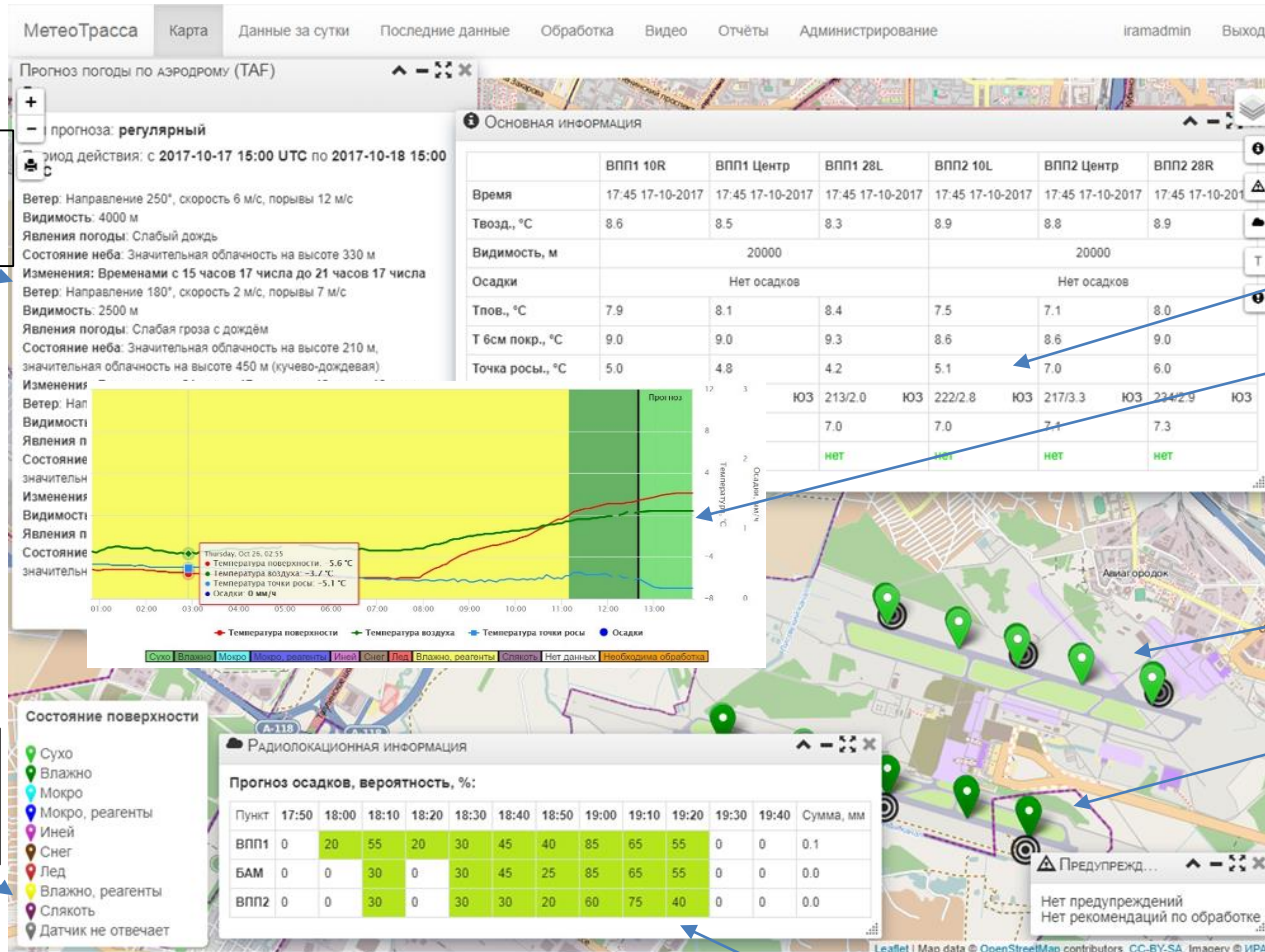
19:03-23:40 – forecast: no fog at the flagged point (MKн 28R), observation: no fog (VIS > 3000 m) at the point and fog at 5 other points => forecast is correct.

Later, fog is forecasted and observed at the flagged point => forecast is correct



# Displays of recent, current and forecast weather for aerodrome service SPb

Regular forecast



Recent, current weather & forecasts for runways

Runway sensors

Surface conditions

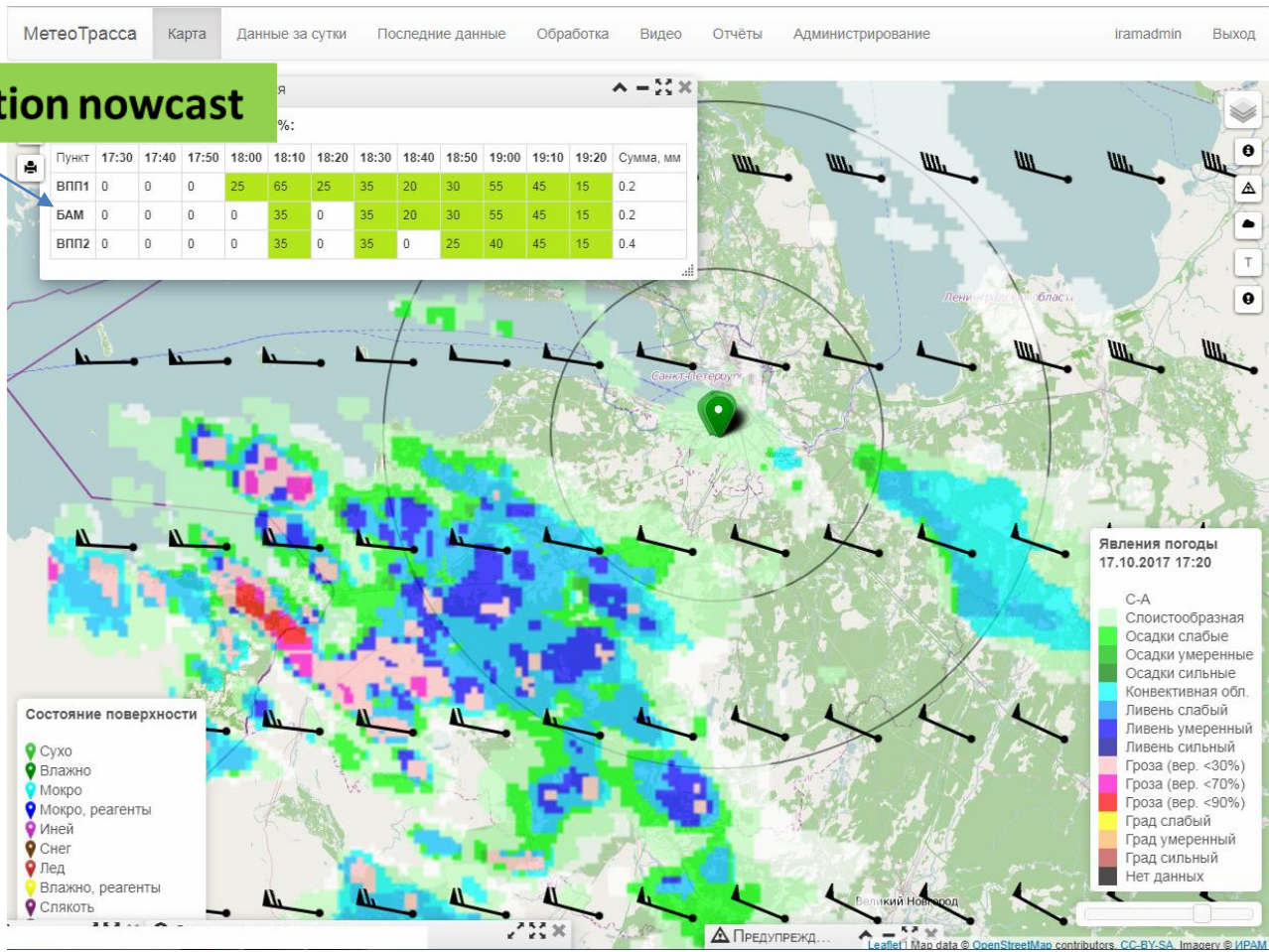
Precipitation nowcast

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

Precipitation nowcast





# MeteoTrassa for aerodrome service

## Yuzhno-Sakhalinsk

Карта    Метео    Анализ данных    Техническое состояние    Помощь    УHSS    Выйти

Openstreetmap  
 Google карта  
 Google гибрид  
 Google земля

Наблюдения

Дорожные станции  
 Датчики поверхности

	ВПП 012 бетон	ВПП 012 асфальт	ВПП Центр асфальт	РД Bravo бетон	ВПП 192 асфальт	ВПП 192 бетон
Время	08:52 28-02-2019	08:52 28-02-2019	08:52 28-02-2019	08:52 28-02-2019	08:52 28-02-2019	08:52 28-02-2019
Твозд., °C	1.0	1.0	1.0	1.0	0.7	0.7
Видимость, м	8000	8000	9000	9000	9000	9000
Осадки	Нет осадков	Нет осадков	Нет осадков	Нет осадков	Нет осадков	Нет осадков
Тпов., °C	-0.1	-1.2	-0.5	-0.4	-0.1	-0.6
Т бсм покр., °C	2.2	1.2	2.1	2.2	3.0	1.8
Точка росы., °C	-5.8	-5.8	-5.6	-5.6	-5.2	-5.2
Ветер., °/м/с напр.	250/2.5	3 250/2.5	3 238/2.7	ЮЗ 238/2.7	ЮЗ 235/2.4	ЮЗ 235/2.4
Тпрогн. пов. +4ч, °C	-2.1	-2.8	-3.0	-3.1	-2.7	-3.4
Прогн. гололеда	нет	нет	нет	нет	нет	нет

Предупреждения по аэродрому (время UTC)

УHSS ПРЕДУПРЕЖДЕНИЕ ПО АЭРОДРОМУ 1 280820  
ДЕЙСТВИТЕЛЬНО 280830/281100 Т МИН НОЛЬ ГРАДУСОВ  
ПРОГНОЗИРУЕТСЯ=

Рекомендации по обработке

08:52 28-02-2019 ВПП 012 бетон : Нет рекомендаций.  
08:52 28-02-2019 ВПП 012 асфальт : Нет рекомендаций.  
08:52 28-02-2019 ВПП Центр асфальт : Нет рекомендаций.  
08:52 28-02-2019 РД Bravo бетон : Нет рекомендаций.  
08:52 28-02-2019 ВПП 192 асфальт : Нет рекомендаций.  
08:52 28-02-2019 ВПП 192 бетон : Нет рекомендаций.

Прогноз погоды по аэродрому (время UTC)

Тип прогноза: **Регулярный**  
Период действия: с 28 февраля 2019 г., 09:00 UTC по 1 марта 2019 г., 15:00 UTC

Ветер: Направление 190°, скорость 3 м/с  
Видимость: 3100 м  
Явления погоды: Мгла  
Облачность: Значительная облачность на высоте 900 м (кучево-дождевая)  
Изменения: Временами с 09 часов 28 числа до 23 часов 28 числа  
Видимость: 1400 м  
Явления погоды: Дымка. Дым  
Облачность: Значительная облачность на высоте 330 м, значительная облачность на высоте 690 м (кучево-дождевая)  
Изменения: С 00 часов 00 мин 29 числа  
Ветер: Направление 210°, скорость 3 м/с  
Видимость: 10 км или более  
Облачность: Значительная облачность на высоте 810 м (кучево-дождевая)

Состояние поверхности

- Сухо
- Влажно
- Мокро
- Мокро, реагенты
- Иней
- Снег
- Лед
- Влажно, реагенты
- Слякоть
- Нет данных

Surface condition, wind

Warnings

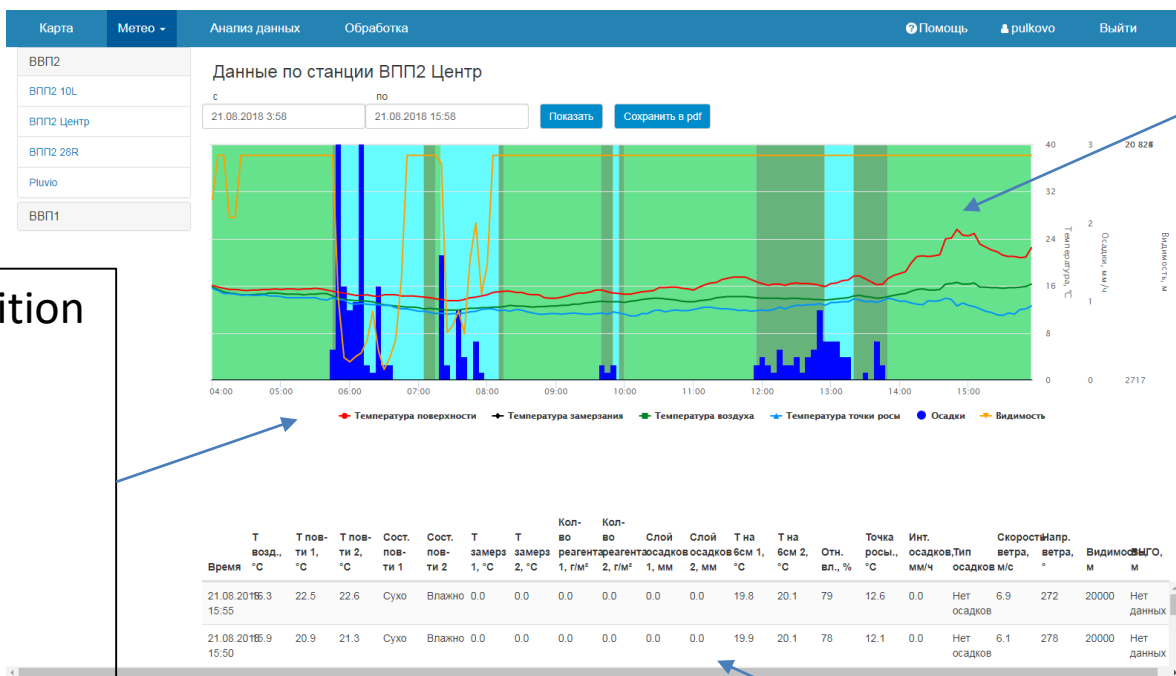
Current weather, forecasts

TAF

Recommendations on surface treatment

# MeteoTrassa for aerodrome service

## Yuzhno-Sakhalinsk



Measurements and forecasts

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

All measurements





# Verification is available on the website

Метеоэксперт: верификация прогнозов

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  
 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 явления

H = a/(a+c) коэффициент попаданий  
 F = b/(b+d) коэффициент ложных тревог  
 FAR = b/(a+b) отношение ложных тревог к общему числу прогнозов

Интервал значений: [0,1]  
 Идеальное значение: 1

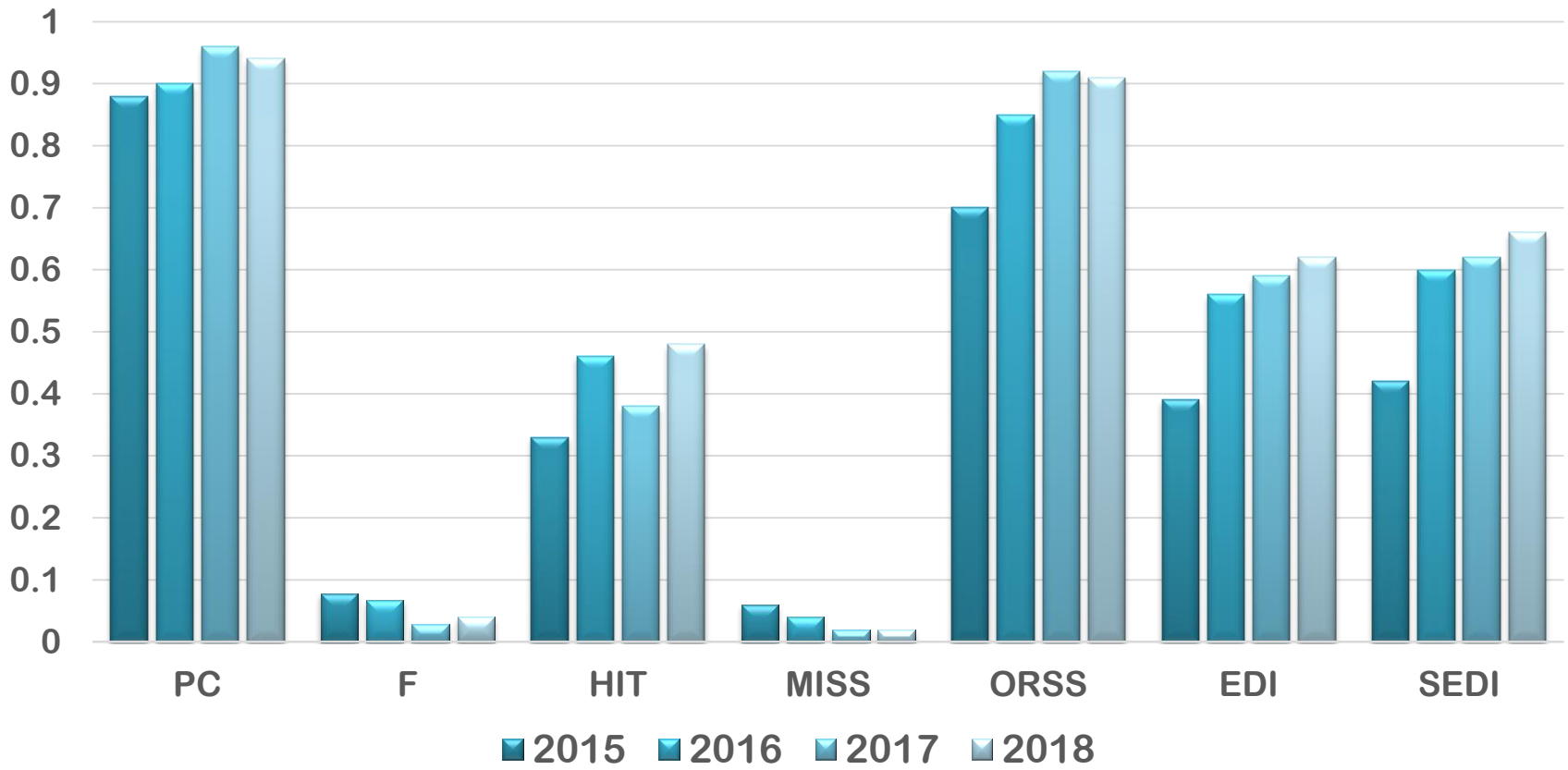
Институт радарной метеорологии | meteocube@iram.ru

- **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



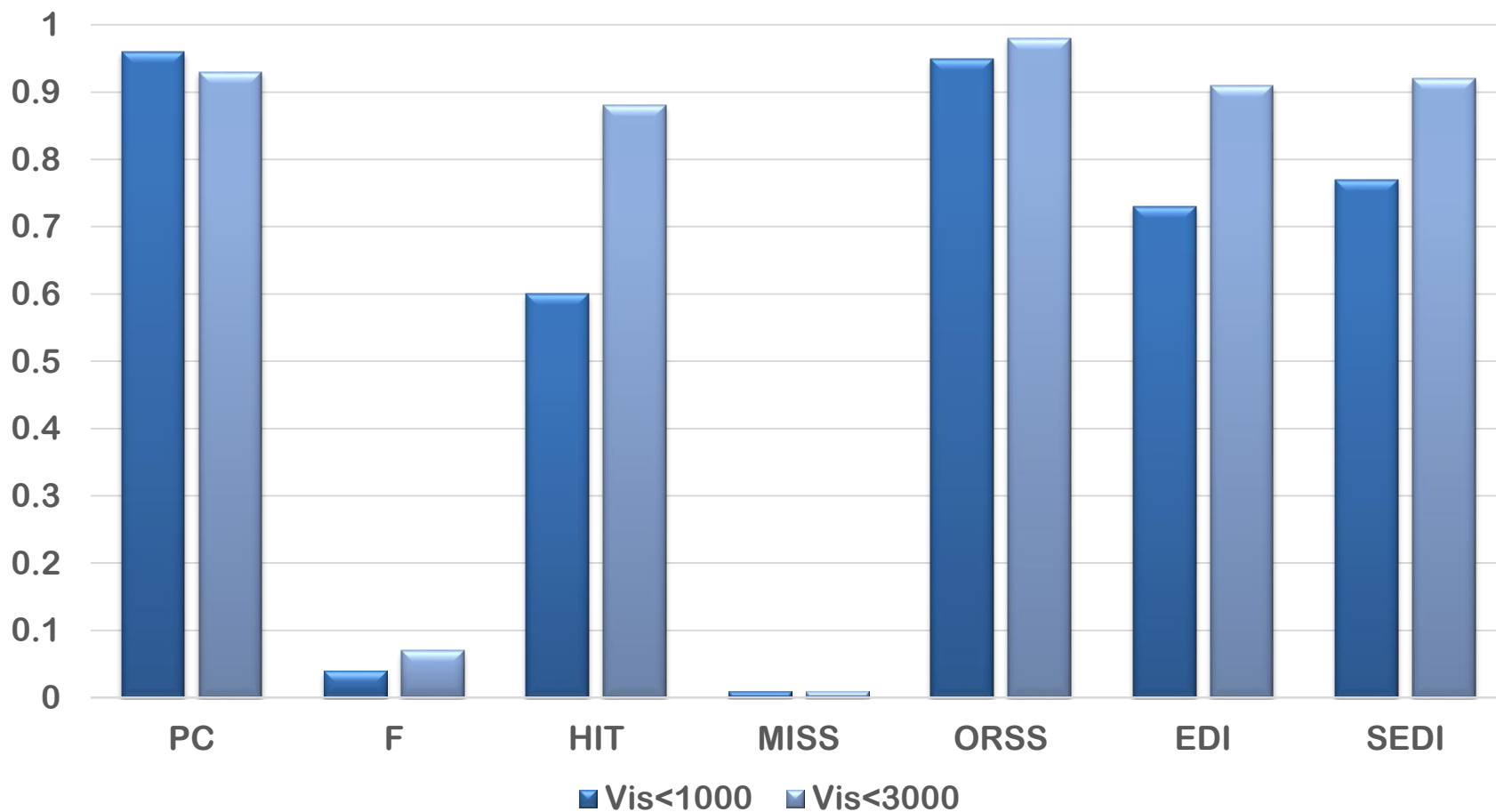
Range: [0,1]    [0,1]    [0,1]    [0,1]    [0,1]    [-1,1]

Underlined symbols correspond to ideal values



# Visibility forecast verification

for the operation period over 2018.09 – 2019.03 in SPb



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

