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Air monitoring system of the Krasnoyarsk Science Center SB RAS

Valery Zavoruev[1], *Alexey* Kadochnikov[1], *Alexey* Tokarev[2,*]

[1]Institute of Computational Modeling SB RAS, Krasnoyarsk, Russia
[2]Federal Research Center Krasnoyarsk Science Center SB RAS, Krasnoyarsk, Russia

Abstract. The paper deals with the problem of monitoring the surface layer of the atmosphere of the Siberian city of Krasnoyarsk with a population of one million people in order to study the regularities of the formation of a space-time field of particulate matter concentrations in the air. It is shown that such research can be performed only with the help of a system of scientific monitoring of atmospheric air. The Krasnoyarsk Scientific Center SB RAS air monitoring system is a set of special equipment and software designed to collect and analyze objective data on the state of atmospheric air in Krasnoyarsk. The main task of creating and operating the monitoring system is to form an information and analytical basis for research and development aimed at solving the problems of improving the environmental situation in Krasnoyarsk. The article presents the results of almost two years of experience in the operation of the monitoring system and the main results.

1 Introduction

The state air monitoring system is regulated by a variety of regulatory documents. Due to this circumstance, the introduction of advanced and generally recognized in many countries technologies and means of monitoring the state of the air environment is practically not implemented in Russia. For example, Hydrometcenter of Russia (Hydrometeorological Research Center of Russian Federation) still measures suspended matter, while many years of international experience show that it is necessary to control particulate matter. It has been shown that it is particulate matter that have a very negative effect on human health [1, 2].

At the level of the constituent entity of the Russian Federation, a regional environmental monitoring system has been created, the operator of which is a subordinate institution of the Ministry of Ecology of the Territory. As part of this system in Krasnoyarsk and the suburbs, there are nine automated observation posts (AOP), where particulate matter concentrations are measured. However, the information received cannot be interpreted in an accessible and understandable form for the population due to bureaucratic reasons prescribed in the regulatory legal acts of Hydrometcenter of Russia.

The residents of Krasnoyarsk are particularly concerned about the smog phenomena, which the people and the media call "black sky". The intensity of the smog is determined by

* Corresponding author: oleg@icm.krasn.ru

the concentration of particulate matter. In this regard, it becomes necessary to study the regularities of the formation of the spatio-temporal field of concentrations of particulate matter in the surface layer of the atmosphere of the city of Krasnoyarsk. For such study of the air environment over the territory of one million city, nine AOP equipped with dust meters are clearly not enough. This problem can be solved by installing relatively cheap air monitoring stations that measure PM concentration and some meteorological parameters [3].

The above circumstances have necessitated the development of a system for scientific monitoring of the air environment. Systems of this type are now being created in many regions, countries and cities of the world [4-8].

2 Subject of research

2.1 Air monitoring system

The air monitoring system of the Krasnoyarsk Scientific Center of the Siberian Branch of Russian Academy of Sciences (hereinafter referred to as the System) is a set of special equipment and software designed to collect and analyze objective data on the state of atmospheric air in Krasnoyarsk, which, firstly, includes certified and calibrated automatic stations for monitoring atmospheric air pollution (monitoring stations), recording the characteristics of the atmosphere and transmitting this information to a centralized database via a cellular network. Secondly, there are special software tools such as embedded software of monitoring stations and a web interface for their administration, a subsystem for storing registered data and software interfaces for their loading through web services, tools for operational data processing and visualization [9].

The main task of creating and operating the System is to form an information and analytical basis for scientific research and development aimed at solving the problems of improving the environmental situation in Krasnoyarsk.

2.2 Measured indicators

The System contains two blocks of information: meteorological characteristics and data on air pollution.

Meteorological characteristics are temperature (in degrees Celsius), pressure (mm Hg), relative humidity (percent).

Air pollution data is the concentration of particulate matter (PM) with a diameter of less than 10 microns (PM10) and less than 2.5 microns (PM2.5) in the ambient air.

2.3 Air Quality Index

Instant AQI air quality index is calculated based on measurements of suspended particles concentration in the System.

The Air Quality Index (AQI) is a widely used worldwide tool for providing information on ambient air pollution in a simple and visual form. In the System, it is currently calculated based on the concentrations of particulate matter (PM10 and PM2.5), which are recalculated (normalized) by piecewise linear interpolation to a single scale of pollution levels (from 0 to 500 units). For each class of this scale, a color designation is also introduced. The main idea of the AQI is to present data on air pollution in terms of human health impact levels.

Along with the basic indicator – the air quality index AQI – its modifications are widely used in practice: NowCast AQI, Asian AQI, Instant AQI (InstantCast AQI), etc. They use revised calculation formulas, in which the averaging of suspended solids concentrations is not performed in 24 hours as in the case of AQI, but in a shorter period – 12 hours (NowCast AQI) or 1 hour (Instant AQI). The result is more objective operational information about air quality; that is why such modifications are recommended for use in public warning systems. The System provides the Instant AQI (instantaneous, operational AQI).

The color-coded AQI index scale shows how air pollution affects human health; on its basis, recommendations were formulated for the population to stay in the open air.

3 Materials and methods

The system is based on many years of experience in scientific research and development in the field of solving problems of environmental monitoring and assessment of the state of the natural environment by a team of authors from the Institute of Computational Modeling SB RAS (ICM SB RAS) [10].

The software and technological platform for development is the Geoportal of the ICM SB RAS, including its subsystem "Operational monitoring data".

23 certified CityAir air monitoring stations developed by a group of companies from the Novosibirsk Technopark and the Skolkovo Innovation Center are used as the basic equipment of the air monitoring system of the Krasnoyarsk Scientific Center of the SB RAS.

To assess the data coming from the CityAir air monitoring stations, information from four AOP is used on atmospheric air pollution from the Regional Departmental Information and Analytical System of Data on the State of the Environment of the Krasnoyarsk Territory, which is operated by the Regional State Budgetary Institution Center for the Implementation of Environmental Management and Protection Measures the environment of the Krasnoyarsk Territory". This work is carried out within the framework of intensive information and technical interaction and cooperation, with the support of the regional Ministry of Ecology.

The developed software for the environmental monitoring system structurally consists of a set of interrelated components. The core of the development is a service-oriented data transmission system and a geospatial database, which receives all the collected information. A set of web interfaces, including those adapted for mobile devices, has been created to present data to end users. Data visualization is carried out in several forms: on a map and using a specialized table (Fig. 1).

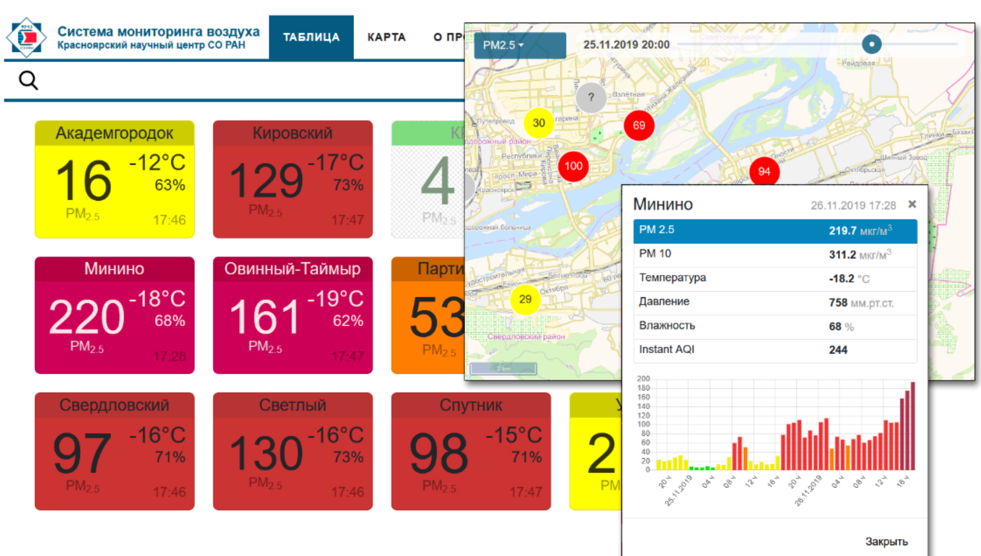

Fig. 1. Air monitoring system user interface.

A tabular view of monitoring posts is shown in Fig. 1 on the left side. All posts are displayed as separate "cards" with the ability to search by title and sort. The card contains up-to-date data on air pollution and meteorological information. The color scheme reflects the degree of hazard according to the AQI scale. By selecting a separate post, the user opens an extended view of data with the dynamics of changes in indicators for the last 2 days or a month.

The cartographic presentation of the data (in Fig. 2 on the right) provides display of the hourly averaged pollution values at each observation point, with the ability to scroll through the values for the last 3 days.

4 Results and discussion

The system has been operating steadily since October 2018. The advantages of the System include the fact that it stably operates at temperatures of minus 35-40 °C. Under these conditions, measurements on the edge ALP are not carried out for technical reasons. Thus, using the System, for the first time, the concentration of PM2.5 in the atmosphere of the city of Krasnoyarsk was determined during the period of severe frosts [5].

In addition, on the basis of the data obtained using the System, studies are carried out on the regularities of pollution during anticyclones and the effect of forest fire smoke, PM2.5 concentration fields are studied depending on the relief of the city territory and the proximity of the non-freezing Yenisei River.

A comparative analysis of the data for 4 winter months was carried out from 01.11.2019 to 29.02.2020. Graphs of daily average values averaged over all 7 posts of the regional system of the Ministry of Ecology of the Territory (dashed red graph) and averaged over all 16 monitoring stations of the Federal Research Center of the KSC SB RAS (solid blue graph) are shown in Fig. 2.

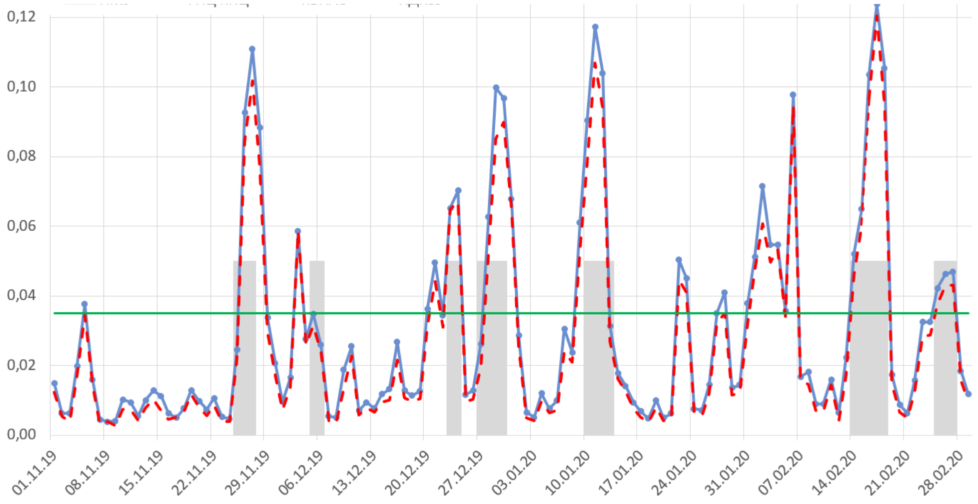

Fig. 2. PM2.5 particulate matter concentrations (mg/m^3), averaged over monitoring stations in Krasnoyarsk from November 2019 to February 2020. Here are the periods of unfavourable weather conditions announced by state services (gray blocks), the level of average daily maximum allowable concentrations (green line), monitoring data from two independent city monitoring systems (dashed red & solid blue graphs).

This presented graph also shows the days on which the mode of unfavourable meteorological conditions (UMC) was announced, this was 7 times during the period under consideration, and the standard for the average daily maximum permissible concentration PM2.5 = 0.035 mg/m^3.

The mean values of PM2.5 concentrations at the monitoring stations for this period are shown in Fig. 3. Analysis of the presented spatial distribution of PM2.5, taking into account the inhomogeneity of the relief, suggests that the pollution of the city's atmosphere in the winter period is primarily due to autonomous heat supply sources (stove heating).

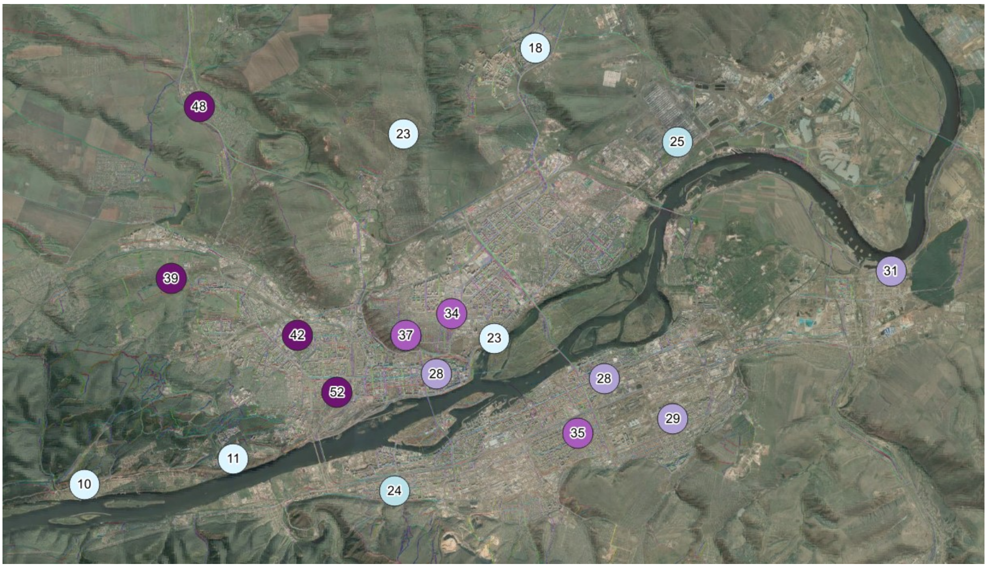

Fig. 3. Average concentrations of particulate matter PM2.5 (μg/m^3) in winter (for 4 months, from November 2019 to February 2020) at monitoring stations in Krasnoyarsk.

5 Conclusions

Within the framework of the presented interdisciplinary research, a development was designed and implemented based on solving the problems of studying the characteristics of the natural environment of a million-strong city and creating information and computing technologies for the development of an effective service-oriented analytical system.

As a result, a network of scientific research monitoring of atmospheric pollution in a large industrial city was formed, based on a large number of spatially distributed operational monitoring stations. This network provides capabilities for detailed spatial and temporal data analysis. For example, it is possible to determine the centers of the initial appearance of pollutants, to trace the dynamics of the spread of pollution across the territory at the level of individual microdistricts of the city. Such data can help to identify sources of pollution, to reveal the characteristic tendencies of its distribution.

The preliminary results of processing the obtained information show a significant effect of furnace heating on the pollution of Krasnoyarsk. The unevenness of the relief, along with the speed and direction of the wind, largely determines the characteristics of the spread of pollution in the city.

Further research in this area is needed to obtain reliable results, analyze the pollution situation and justify proposals for regional authorities.

References

1. Song C., He J., Wu L., Jin T., Chen X., Li R., Ren P., Zhang L., Mao H. Environ. Pollut. **223**, 575 (2017)
2. S. Gulia, S.M. Shiva Nagendra, M. Khare, I. Khanna. Atmospheric Pollution Research, **6** (3), 286-304 (2015)
3. Changqing Lin et al. Atmospheric Environment. **227**, 117410 (2020)
4. M. Ghodousi, F. Atabi, J. Nouri, A. Gharagozlou. Polish Journal of Environmental Studies, **26** (2), 593-603 (2017)
5. Xuezhen Qiu et al. Frontiers of Environmental Science & Engineering, **9** (6), 1056 (2015)
6. T. Savu, B.A. Jugravu, D. Dunea. REVISTA DE CHIMIE, **68** (4), 796 (2017)
7. L. Hu, P. Yue, M. Zhang, J. Gong, L. Jiang, X. Zhang. Earth Science Informatics, **8** (3), 511 (2015)
8. Hua Wang et al. Journal of Environmental Sciences, **29**, 178 (2015)
9. Kadochnikov A.A., Tokarev A.V., Zavoruev V.V., Yakubailik O.E. IOP Conference Series: Materials Science and Engineering. **537** (6), 062052 (2019)
10. Yakubailik O.E., Kadochnikov A.A., Tokarev A.V. Optoelectronics, Instrumentation and Data Processing, **54** (3), 243 (2018)