Assessment of the influence of weather conditions on the concentration of PM$_{2.5}$ in the atmosphere of Krasnoyarsk

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Abstract. The influence of weather and terrain on the seasonal distribution of surface concentration PM$_{2.5}$ in the atmosphere of the city of Krasnoyarsk (Russia) in 2018-2019 is analyzed. We use data from the Geoportal developed by the authors, which has a data connection with the regional monitoring system of weather conditions (wind direction and speed, relative humidity and air temperature, atmospheric pressure) and particle concentration PM$_{2.5}$.

1. Introduction
The sources of PM$_{2.5}$ in the Earth's atmosphere are natural and anthropogenic processes. Subsequent pollution of urban areas depends on the daily and seasonal changes in weather conditions, as well as the terrain and covers the territories of individual cities and regions of the countries.

Daily variations in PM$_{2.5}$ and PM$_{10}$ concentrations were determined [1] in Milan in 1997-1998 under various thermodynamic conditions of the planetary boundary layer. The highest PM$_{2.5}$ concentration was 125 µg/m$^3$ in winter and 80 µg/m$^3$ in summer, which was attributed by the authors to the location of the city and the meteorological conditions. A multivariate analysis of elements, gaseous pollutants and mass concentration datasets revealed four primary sources contributing to PM$_{10}$ and PM$_{2.5}$ contamination: vehicles exhaust emissions, resuspended crustal dust, secondary sulphates and industrial emissions. In 2013-2014, the dependence of PM$_{2.5}$ on temperature, relative humidity and wind speed in El Paso, Texas was investigated [2]. As a result, a seasonal dependence of PM$_{2.5}$ on meteorological factors was found. Paper [3] studies variability of the major air pollutants in London over the period 2000-2012 and compares them to the levels of pollution in Moscow. Contribution of meteorological factors to the particulate pollution during winter 2016 in Beijing was studied by the authors of [4]. They found that the PM$_{2.5}$ pollution levels during the period studied were significantly affected by horizontal dilution and vertical aggregation.

The city of Krasnoyarsk is located in an elongated basin on both sides of the Yenisei River and extends along the course for 25 km. Terrain features and local climatic conditions lead to unfavorable weather conditions. In this situation, the concentration of substances emitted by stationary industrial enterprises, vehicles and stoves of private houses increases in the atmosphere of the city. The accumulation of suspended solids in the atmosphere leads to smog over the city and worsening living conditions of the population, which is about 1 million people. Krasnoyarsk is on the priority list of 20 major cities of Russia with the highest level of air pollution [5].
2. Research methods and instruments

Monitoring of the quality of atmospheric air in the Krasnoyarsk Territory is realized at stationary observation sites. Observation data are automatically transmitted to the Territorial sectoral information and analysis system on the state of environment of the Krasnoyarsk Territory [6]. The system is operated by Krasnoyarsk state budget-funded enterprise ‘Center for implementation of policy measures on natural resources management and environmental safety in the Krasnoyarsk Territory’. Currently, there are 9 automated observation posts in Krasnoyarsk and its suburbs. The posts perform automatic measurement of meteorological parameters and the concentration of pollution in the air with a period of 20 minutes. Pollutants such as nitric oxide, nitrogen dioxide, sulfur dioxide, carbon monoxide are identified. At the end of 2017, dust analyzers of the BAM-1020 model (Met One Instruments Inc., USA) were added to monitor suspended PM$_{2.5}$ particles.

The solution of the tasks of information support of observations of the state of the environment is impossible without the use of modern means of measurement and communication, new computer technologies. Integration of all monitoring components in a single technology minimizes the cost of docking, reduces the time of data exchange and conversion, eliminates information loss, thereby increasing the reliability and efficiency of the systems being created. The subsystem of research monitoring of the Geoportal of the ICM SB RAS [7, 8] supports the collection of data from external sources, the storage and aggregation of data, the automatic calculation of derived indicators, the upload and presentation of data via a web interface. A software adapter has been developed for the regular download of data from observation posts from the RDIAS system, which facilitates the processing and analysis of monitoring data.

3. Results

For the purpose of our study we used data on the level of atmospheric pollution obtained at automated observation sites of the RDIAS system over the period 2018-2019. Figure 2 illustrates average daily PM$_{2.5}$ concentrations across all observation sites. The dashed line indicates the daily average maximum permissible PM$_{2.5}$ concentration as set by WHO. As one can see, critical concentrations are observed from November through to March and in July.

![Figure 1. Daily average PM$_{2.5}$ concentrations across all observation sites for the years 2018 and 2019.](image-url)
In 2018, the annual average PM$_{2.5}$ concentration was 25.3 µg/m$^3$, while MPC$_{DA}$ (WHO) was exceeded for 110 days (30%). In the year 2019, the annual average PM$_{2.5}$ concentration was 20.5 µg/m$^3$; and the daily average PM$_{2.5}$ concentrations went beyond MPC (WHO) for 75 days (20%). The annual average PM$_{2.5}$ concentrations exceed WHO guidelines [9] while remaining within the limits of the Russian Federation standards [10].

![Figure 2](image2.png)

**Figure 2.** Scatter plot of PM$_{2.5}$ concentration dependence on the speed of wind.

![Figure 3](image3.png)

**Figure 3.** Scatter charts of PM$_{2.5}$ concentration depending on the wind direction (a), air temperature (b), atmospheric pressure (c), and relative air humidity (d).
We carried out statistical analysis of variability of PM$_{2.5}$ concentration depending on meteorological conditions: the wind speed and direction, atmospheric pressure, relative air humidity and temperature. Figures 2 and 3 show statistical dependence of PM$_{2.5}$ concentrations (Y-axis) on meteoconditions (X-axis) for the year 2018. Each dot shows concentration recorded during a 20-minute observation interval. The dashed line indicates the MPC$_{MS}$ standard in Russia Federation [10].

A wind rose has been plotted based on the 2018-2019 meteorological data acquired at the observation site ‘AMS Krasnoyarsk experimental field’ belonging to the federal state-funded enterprise ‘Central Siberian Administration for hydrometeorology and environmental monitoring’. The wind chart indicates that the winds blow predominantly from the south-west carrying pollutants away from the city basin through its eastern boundary. The southeastern wind, on the contrary, traps atmospheric pollutants inside the city.

Analysis of the statistical data shows that critical PM$_{2.5}$ concentrations occur mostly under the following set of conditions:

- Wind speed of less than 1 m/s.
- North-east wind direction.
- Air temperatures from -20°C to -30°C.
- Atmospheric pressure from 100 to 102.7 kPa.
- Relative humidity in the range of 70-80%.

4. Conclusion

Based on the platform and tools of the Geoportal, using data from the regional atmospheric air monitoring system of the city of Krasnoyarsk, data were obtained on the dependence of PM$_{2.5}$ concentration on weather conditions in 2018-2019. It is shown that the annual average of PM$_{2.5}$ concentration was 23.4 µg/m$^3$ in 2018 and 18.4 µg/m$^3$ in 2019, which exceeds MPC$_{AA}$ standard introduced by the World Health Organization and is less than the MPC$_{AA}$ set by the Russian Federation.

PM$_{2.5}$ concentrations in excess of the daily average maximum permissible concentration (MPC$_{DA}$ 25 µg/m$^3$) are observed mostly in winter. This is attributed to the meteoconditions associated with the Siberian anticyclone: low temperature, elevated atmospheric pressure and no wind. It is the time when a lot more fuel has to be burnt; hence, the amount of atmospheric pollutants increases while their removal from the city basin is hindered.

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