Bull. Nov. Comp. Center, Num. Model. in Atmosph., etc., 15 (2015), 29–35

The use of meteorological and satellite information for analyzing the snow cover pollution

A.A. Lezhenin, V.F. Raputa, T.V. Yaroslavtseva

Abstract. The auras of technogenic pollution of the snow cover observed from the space, and their dependence on the current weather conditions are investigated. On an example of emissions of weighed substances from the Iskitim cement plant, the numerical reconstruction of fields of losses of dust is carried out. For the periods of snow absence there is a possibility of estimating the pollution aureoles formed in the intervals of a few days to a few weeks.

Keywords: satellite observations, atmosphere, pollution of snow cover, estimate, reconstruction, numerical modeling.

Introduction

The information obtained from satellites makes possible to visualize of the snow cover pollution around cities and large industrial enterprises. The snow cover in satellite images is the background against which there is a gradual development of the contaminated areas. This effect is evident in the periods when there is no snowfall as well as during the snowmelt [1, 2].

To describe the atmospheric pollutants transport processes, methods of mathematical modeling are widely used [3, 4]. With the knowledge of necessary input data, the application of these methods is not problematic. However, in reality, there is a problem of insufficient information. In this case, the simulation of impurities distribution is complicated and carrying out additional theoretical and experimental research is required.

In the winter season of 2012/13 and 2013/14, the study of the snow of dust pollution in the vicinity of the cement plant, located in the town of Iskitim was carried out [5]. This town is located in the south-eastern part of the Novosibirsk region within 55 km from the regional center — the city of Novosibirsk. From the north and from the east of the plant to the industrial site the Berd river flows. The main sources of inorganic dust emission into the atmosphere are two closely located 80 meter-long pipes of diameter 6 meters.

The formation of long-lasting contamination of fields in the vicinity of the industrial enterprize depends on many factors. The determining factors are: height and location of the pollutant sources, the characteristics of gas and particular emissions composition, weather conditions, terrain, etc.

A full description of these conditions for the numerical modeling of the pollution processes, in most cases, is problematic, and results of calculations are often of a scenic character. Therefore it is necessary to attract various kinds of environmental pollution monitoring. Instrumental studies of the air pollution require considerable expenditures, and their fulfilment is, as a rule, episodic. A more efficient method is the use of natural tablets: soil, vegetation and snow cover, as well as remote sensing data.

1. Materials and methods

The objects of this paper were emissions from stationary sources of "Iskitimcement" snow in the town of Iskitim and in its vicinity. The research in question was based on reports of "Iskitimcement" about emissions of the air pollutants from stationary sources in the period of 2012–2013, the results of visual examination and on the physical–chemical analysis of the composition of the snow-water samples. The routes of sampling were located on eight rhumbs in the main emission sources of inorganic dust. Observational points were located at a distance of 0.4–3 km. We have selected 40 samples of snow. This made possible to make a detailed numerical analysis of dust deposition processes in the main sources of the plant, as well as to establish the quantitative patterns of sediments in the snow samples in different areas.

Snow was selected by a plastic tube of diameter 10 cm. At each point from 2 to 10 core snow was taken. Samples of snow melt at room temperature, the value of pH was measured, water was filtered and dried precipitation was weighed.

Analysis of the measurements data has shown that within 1.5 km from the main sources of emissions, the value of pH ranged from 9 to 12. Prevailing dust fallouts occurred in the north-west, north and north-east directions from the cement plant.

Using the asymptotic semi-empirical equation of the turbulent diffusion and the statistical properties of the wind speed distribution and the vertical turbulent exchange in the surface layer of the atmosphere allows us to express the density of the polydispersed particles fallout over a long period of time as the following regression dependence [6]:

$$\bar{q}(r,\varphi) = \frac{\theta_1}{r^{1.5}} P(\varphi + 180^\circ) \exp\Big(-\frac{c}{r}\Big) \int\limits_0^\infty \frac{\omega^{\theta_2} \exp(-\theta_3 \omega t)}{\Gamma(1+\omega)} \Big(\frac{c}{r}\Big)^{\omega} d\omega, \qquad (1)$$

where r, φ are the polar coordinates, $P(\varphi)$ is the ground-level wind rose, $\Gamma(m)$ is the Euler gamma function, θ_1, θ_2, and θ_3 are unknown parameters determined from the observational data.

The results of dust deposition measurements and the values of pH for the points in the north direction are presented in the table.

Table 1. Measured and recovered dust deposition (g/m^2) from the Iskitim cement plant and a pH value in the snow water samples

The direction of sampling	The distance from the source, km	pH	Measurements, g/m^2	Calculation with model (1), g/m^2
N	0.56	11.8	604.2	710.0
N	0.73	11.5	214.4	220.5
N	0.81	11.2	242.4	269.9
N	1.03	10.9	133.9	180.1
N	1.39	9.5	46.9	40.5
N	1.76	9.1	20.0	14.8
N	2.18	7.9	9.6	7.1
N	2.75	8.2	7.4	3.0
NE	0.69	11.5	143.6	145.4
NE	0.92	10.8	58.7	66.4
NE	1.20	10.9	34.1	29.4
NE	1.62	10.6	14.1	11.0
NW	0.76	9.9	521.0	664.1
NW	0.97	9.8	408.6	405.4
NW	1.28	9.1	162.7	129.5
NW	1.97	9.0	74.4	25.4
NW	2.23	9.0	63.3	21.6
NW	2.57	8.5	35.7	14.3

2. Results and discussions

Based on model (1), the numerical reconstruction of the field deposition was conducted. The existence of stable quantitative laws of the dust content in the snowpack in the radial direction relative to the main source was shown. The total field of deposition of dust and the evaluated air emissions in this winter season have been restored. The results of numerical simulation are presented in Figures 1 and 2.

From the analysis of Figure 2, it is clear that the major deposition of dust occurred in the north-west, along the valley of the river Berd. Proceeding from the wind rose, the major dust loading would be expected in the north-

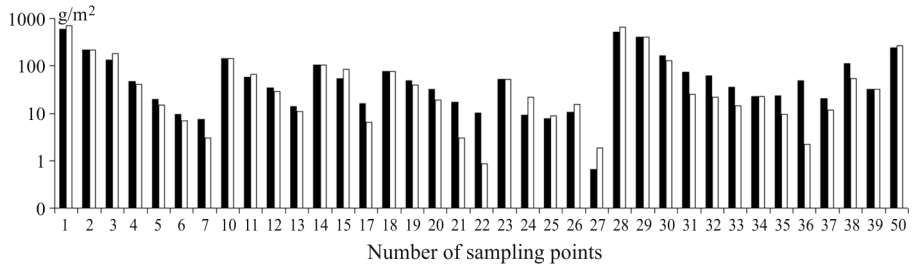

Figure 1. Based on relation (1) measured and restored depositions of inorganic dust (g/m^2) at a snow sampling point

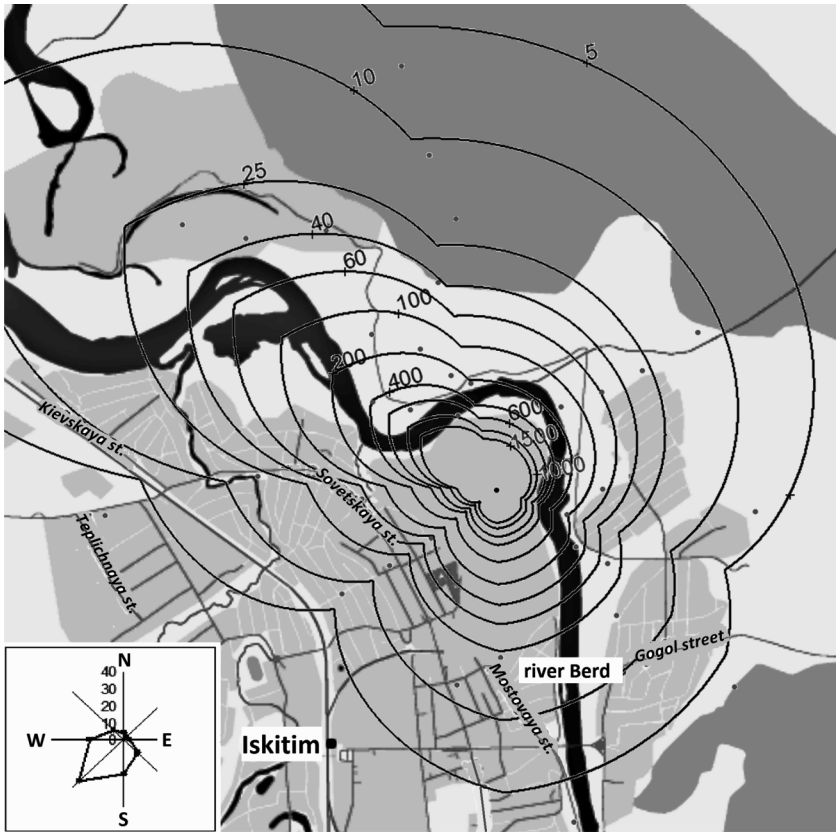

Figure 2. The reconstructed density field of inorganic dust deposition (g/m^2) in the vicinity of the Iskitim cement plant. The winter wind rose of 2012/13

east direction. In our opinion, this phenomenon is explained by peculiarities of the terrain. Figure 3 is a schematic elevation of the surroundings of the town of Iskitim. The analysis of Figure 3 confirms that the configuration of the relief can really have a noticeable impact on the processes of distribution of gas and aerosol in the lower atmosphere. Satellite monitoring allows one to visualize the spatial pattern of the field deposition of dust in the snow. Figure 4 shows a snapshot of the neighborhoods of the Iskitim cement plant taken by the satellite "Landsat-8" of February 7, 2014 (we used the data from the website of the Siberian Center of State Research Center "Planeta").

In the snapshot, there is clearly visible a region of intense pollution of the snow cover. The meteorological station located at a distance of about 3 km from the industrial area of the cement plant did not fix precipitations in the previous 8 days. Consequently, the pollution plume, visible in the satellite snapshot, was formed during the time interval of January, 30 to February 7. In Figure 4, the north-west orientation of the dust removal is clearly seen.

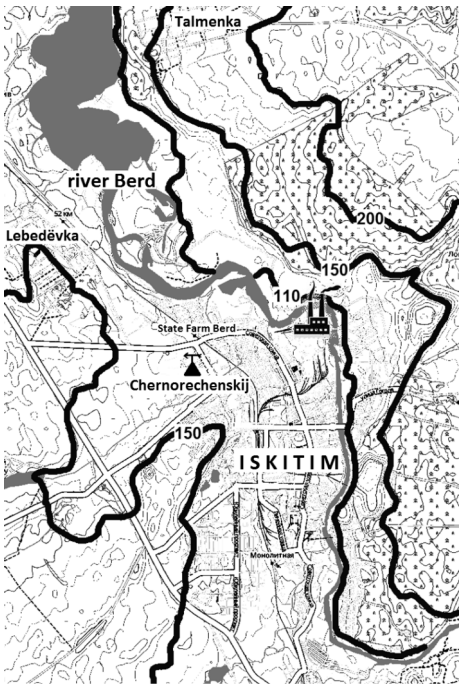

Figure 3. The topography of the Iskitim neighborhood. The black triangle is the weather station of the town of Iskitim

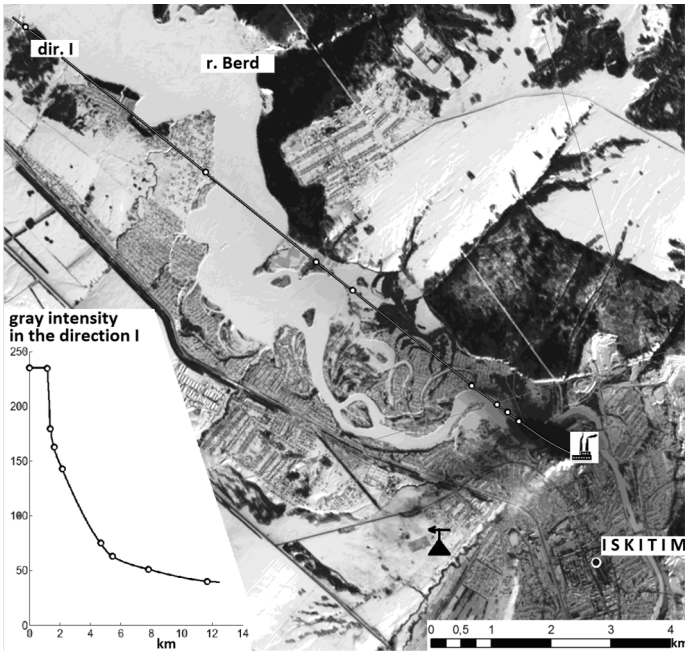

Figure 4. A satellite snapshot of the neighborhood of the Iskitim cement plant of February 7, 2014. In the lower left corner: the intensity of changes in the shades of gray to the north-west of the plant. The black triangle is the position of the Iskitim weather station

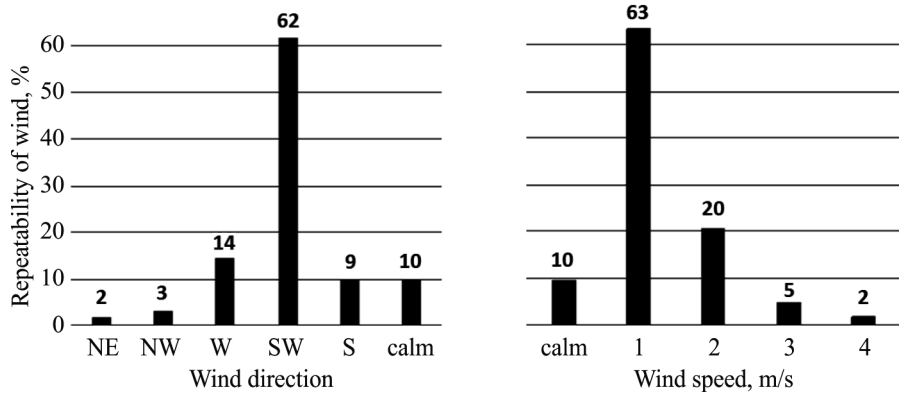

Figure 5. The repeatability of wind directions and speeds at the Iskitim meteorological station in the period of January, 30 — February, 7, 2014

The repeatability of wind directions and speeds at the Iskitim meteorological station is shown on Figure 5. This period is characterized by light winds, the dominant south and south-west winds (over 70 % of cases) and calm conditions (10 %).

3. Conclusion

Using meteorological data and satellite snapshots of the snow cover pollution, a significant effect of the terrain on the formation of dust deposition from the fields of a tall pipe of the Iskitim cement plant was established. In the winter season, the main contaminant removal takes place in the northwest, along the valley of the river Berd. The measurements at the Iskitim meteorological station fixes the predominance of the south-west and southern winds. This contradiction is explained by the orographic features of the area, the presence of elevated landforms on the right bank of the river Berd, and often there is a steady temperature stratification in the lower atmosphere. Analysis of the data monitoring of the snow cover pollution during the winter period of 2012–2014 confirms the above considered [5].

Note that complex terrain data from the nearby weather stations may not reflect the actual wind field. Therefore it is very difficult to use conventional techniques [7, 8], to calculate the concentrations of impurities fields. In our opinion, conducting the monitoring studies is a necessary stage in the study of the processes of technogenic pollution of areas.

In the conventional approach, successive satellite snapshots during the snowmelt in the winter season can detect the areas of pollution from industrial plants [1, 2]. This approach significantly limits the possibility of using the cosmic data obtained during the winter season. In our opinion, to maximize the use of this information, it is advisable to use the data of the

current weather conditions. Then, during the snowfall periods it is possible to estimate an intermediate zone of technogenic pollution. In particular, in the areas under the influence of the Siberian anticyclone during the winter season in the absence of clouds, with the help of satellite snapshots it is possible to monitor pollution haloes formed in the period ranging from several days to several weeks.

References

[1] Prokacheva V.G., Usachev V.F. Snow cover as an indicator of the cumulative impact of pollution in cities and roads // Meteorology and Hydrology. — 2013. — No. 3. — P. 94–106 (In Russian).

[2] Prokacheva V.G., Usachev V.F. Siberian Federal District of Russia. Contamination of Land by Districts, Urban Settlements and in River Catchments. — S.-Petersburg: LEMA, 2010 (In Russian).

[3] Atmospheric Turbulence and Air Pollution Modeling / Ed. F.T.M. Nistada and H. Van Dopa. — Leningrad: Gidrometeoizdat, 1985 (In Russian).

[4] Aloyan A.E. Simulation of the Dynamics and Kinetics of Trace Gases and Aerosols in the Atmosphere. — Moscow: Nauka, 2008 (In Russian).

[5] Shcherbatov A.F., Raputa V.F., Turbinsky V.V., Yaroslavtseva T.V. Evaluation of air pollution by dust according snow selection based reconstruction deposition of the snow fields fallout // Analysis of Health Risk. — 2014. — No. 2. — P. 42–47 (In Russian).

[6] Raputa V.F. Numerical reconstruction of radioactive contamination from the accident at the radiochemical plant in Tomsk-7 // Optics of Atmosphere and Ocean. — 2012. — Vol. 25, No. 8. — P. 733–737 (In Russian).

[7] The Methodology for Calculating the Concentration in the Air of Harmful Substances in Industrial Emissions. OND-86 / Ed. M.E. Berlyand, N.K. Gasilin, E.L. Genihovich, et al. — Leningrad: Gidrometeoizdat, 1987 (In Russian).

[8] Garger E.K., Naydenov A.V. To comparison of different methods of calculation of the field of the impurity concentration of the high-altitude source // Proc. IEM. — 1986. — Vol. 37 (120). — P. 66–85 (In Russian).