AEROSOL TRANSFER IN THE ATMOSPHERE: SIMULATION EXPERIMENTS

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A simulation experiment with a model for atmospheric aerosol transfer with real meteorological data for the Siberian region is described based on the monotone finite difference scheme and the single-parameter model of the atmospheric boundary layer.

To study aerosol migration and perform ecological examination and expert's assessments, the MAP system for modeling atmospheric processes and pollutant transfer in the Siberian region is developed in the Institute of Computation Technologies[2] within the framework of the project "Siberian Aerosols".[1]

The equation describing pollutant spread in the atmosphere in the coordinate system (x, y, p) can be presented in the following form:

$$\frac{\partial\varphi_i}{\partial t} + u\,\frac{\partial\varphi_i}{\partial x} + \nu\,\frac{\partial\varphi_i}{\partial y} + (\tau - \tau_g)\,\frac{\partial\varphi_i}{\partial p} = \frac{\partial}{\partial x}K_x\frac{\partial\varphi_i}{\partial x} + \frac{\partial}{\partial y}K_y\frac{\partial\varphi_i}{\partial y} + \frac{\partial}{\partial p}K_p\frac{\partial\varphi_i}{\partial p} + C_i + P_i + S_i\,, \quad (1)$$

where φ_i is volume concentration of the ith component; u, ν, τ are wind velocity components; τ_g is the rate of aerosols sedimentation due to gravitation; K_x and K_y are the coefficients of horizontal diffusion; K_p is the coefficient of vertical diffusion; C_i is the term taking into account chemical transformations; P_i is the term taking into account pollutant washing out by precipitation; S_i is the emission source of the ith component.

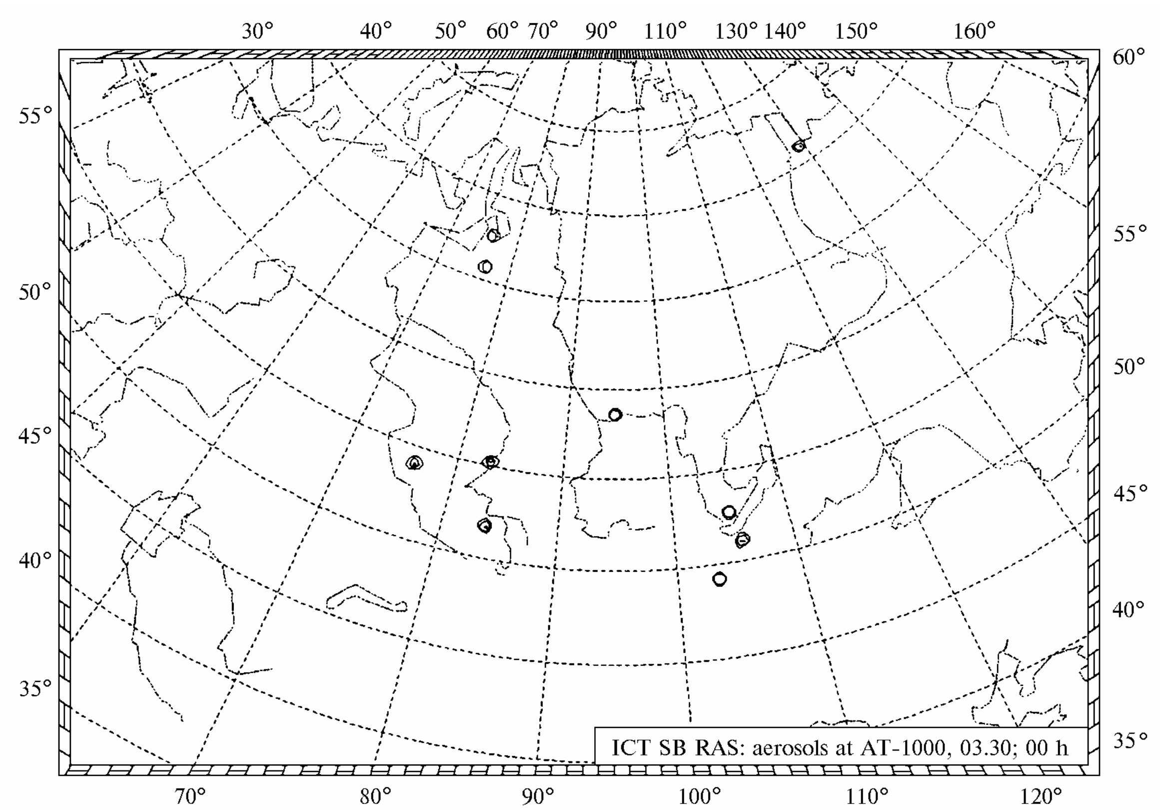

FIG. 1. The network of aerosol monitoring in Siberia.

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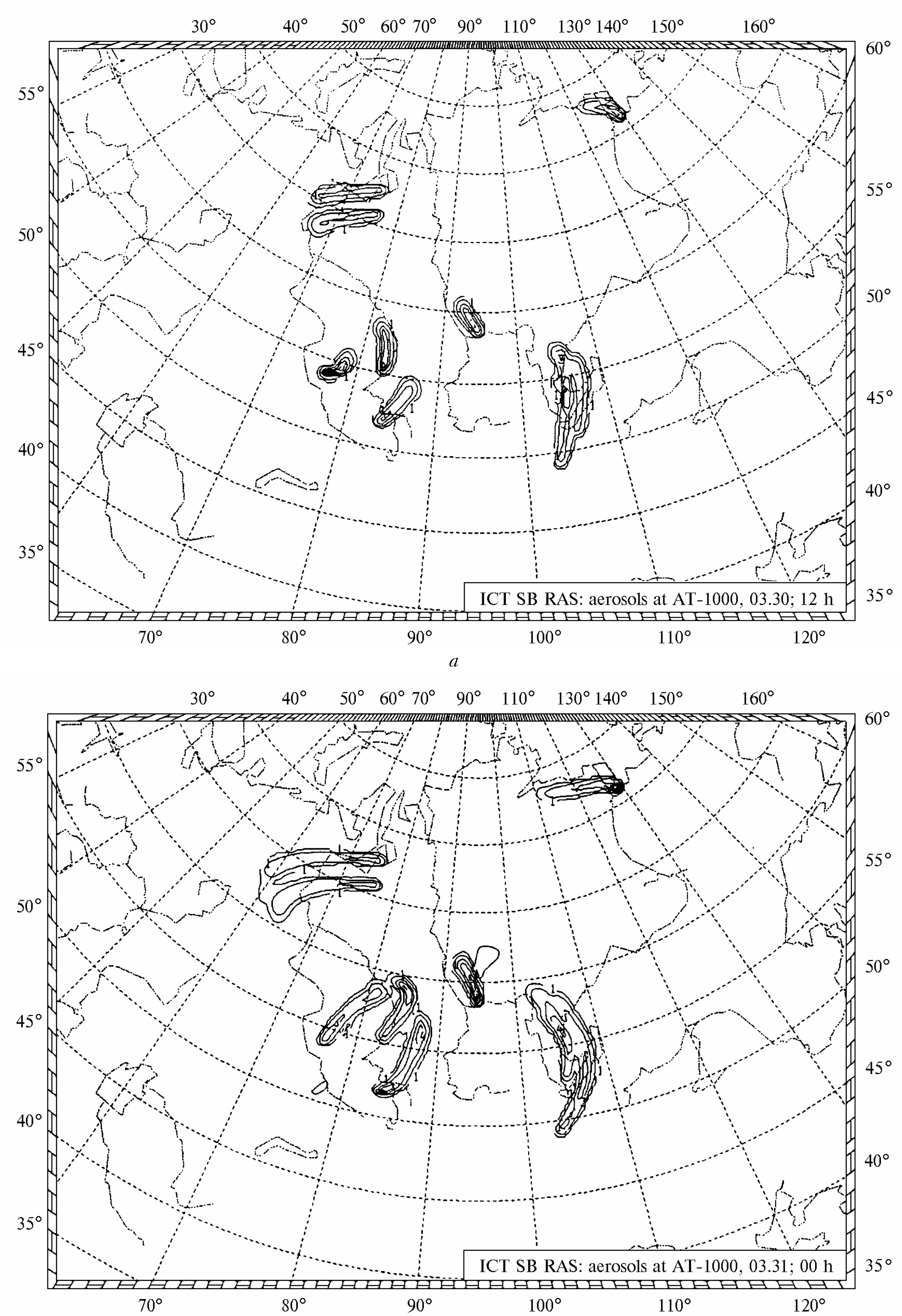
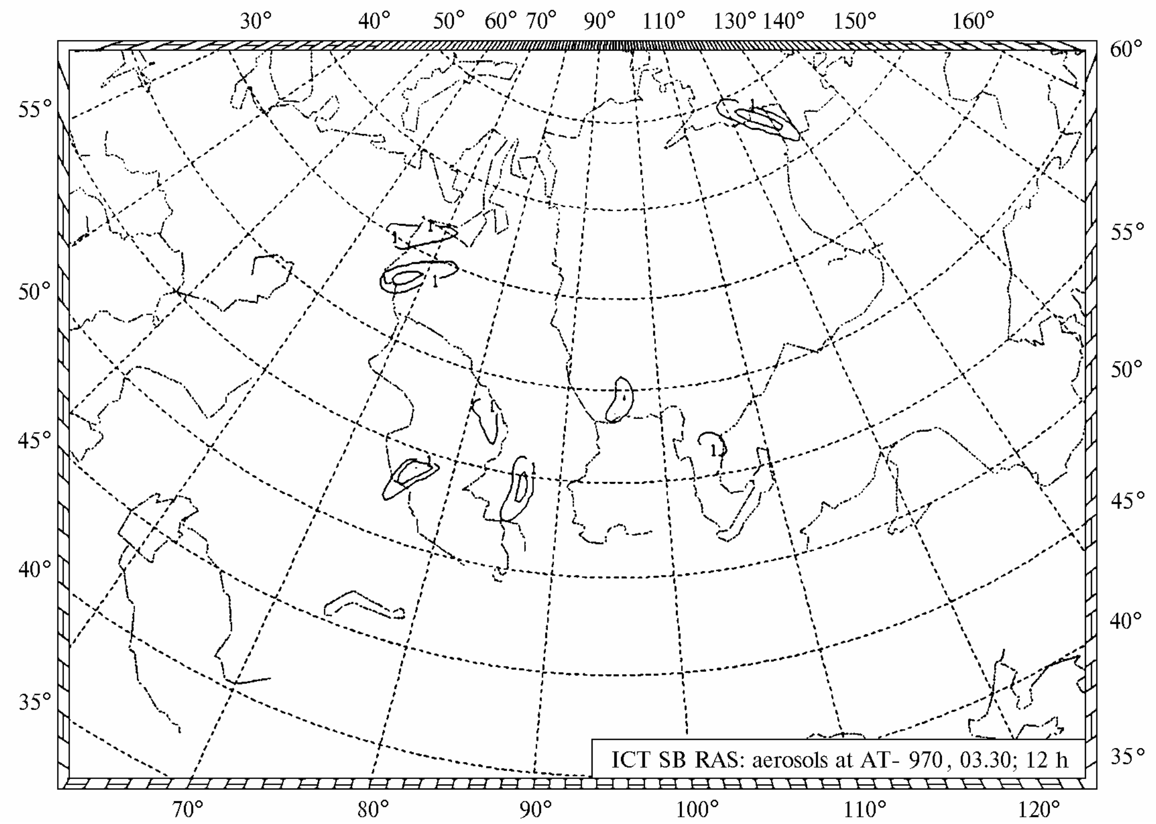
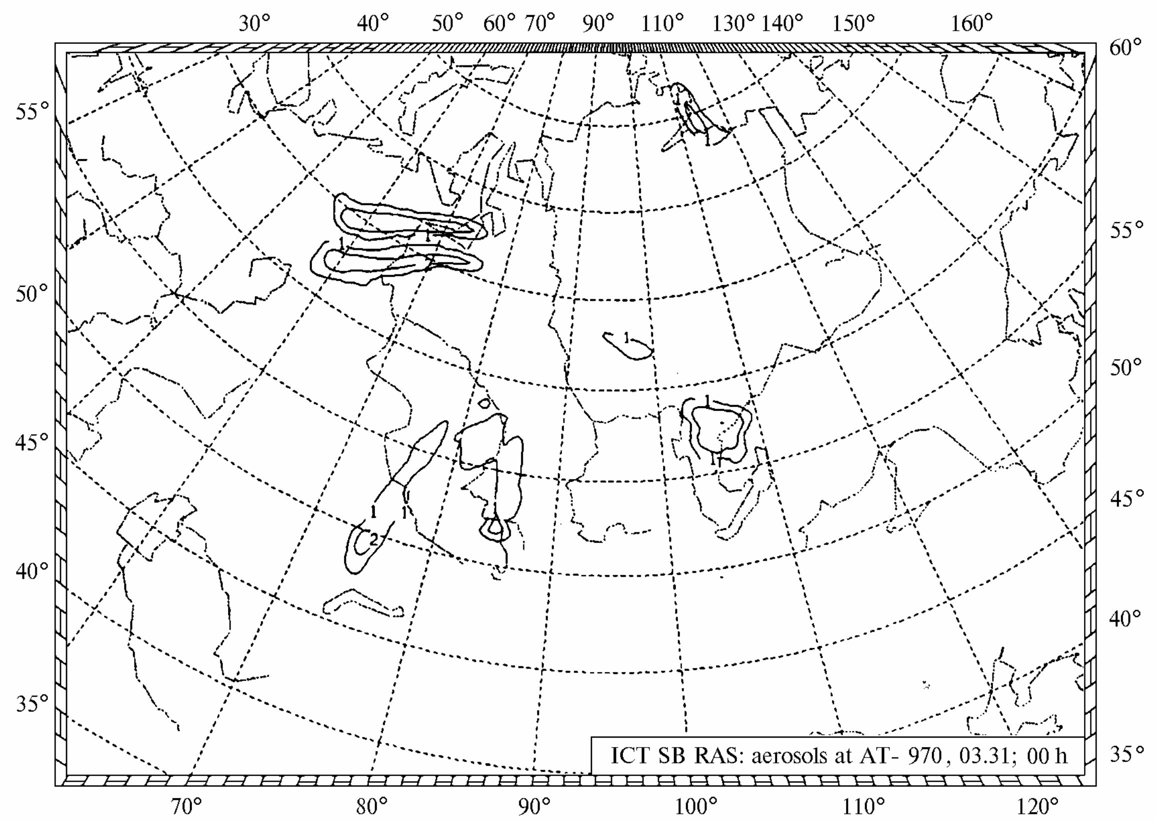


FIG. 2. Fields of aerosol concentration at a surface of 1000 hPa *for* 12:00 *(a) and* 24:00 L.T. *(b).*



a



b

FIG. 3. Fields of aerosol concentration at a surface of 970 hPa *for* 12:00 *(a) and* 24:00 L.T. *(b).*

Equation (2) is taken as an initial condition; Eqs. (3) and (4) are used as boundary conditions at the lower and upper boundaries of the domain D of functions $\varphi_i(x, y, p, t)$, respectively

$$\varphi_i\Big|_{t=0} = g_i(x) \ , \tag{2}$$

$$K_p \frac{\partial \varphi_i}{\partial p} - \beta\varphi_i = 0 \ , \tag{3}$$

$$\varphi_i = 0 \ , \tag{4}$$

Here g_i are given functions; β is the parameter characterizing pollutant interaction with the underlying surface.

At the lateral boundaries ∂D, concentration is supposed to be zero

$$\varphi_i\Big|_{(x,\, y,\, p)\, \in\, \partial D} = 0 \ . \tag{5}$$

To study the properties of the developed model with real meteorological data, a simulation experiment was performed for 10 sites in the Siberian region where concentration of different aerosols was measured during several years.[1] Calculation on simulation of three separate emissions in the atmosphere was performed in Ref. 3. In Ref. 4, emissions were bounded by a certain value similar to maximum permissible concentration. In our experiment, we consider continuous emission into the atmosphere and process information about aerosol concentration at a level of 1000 hPa at the ten above-mentioned sites. Besides, we add simulation and transfer at four additional levels in the boundary layer of the atmosphere.

Parametrization of processes in the boundary layer of the atmosphere and the value of the vertical diffusion coefficient are performed similarly to Ref. 4. In order to solve Eq. (1), like in Ref. 4, we use the method of splitting by physical processes[5] on the base of the Bott scheme.[6]

The transfer model uses grid with step of 30 km along horizontal variables (251 × 211 grid nodes) and 19 levels along the vertical (15 standard levels, i.e., 10, 20, 30, 50, 70, 100, 150, 200, 250, 300, 400, 500, 700, 850, 1000 hPa, and four additional levels for describing the boundary layer of the atmosphere: 880, 910, 940, 970 hPa). The initial fields of wind velocity are defined similarly to Ref. 4. Coefficient β was assumed to be 0.01 hPa in this experiment. Besides, local transformations of pollutants and their washing out by precipitation were neglected.

Figure 1 presents 10 sites where aerosol concentration was measured. The results of the simulation experiment are characterized by isolines of the aerosol concentration field shown in Figs. 2 and 3. The isolines are obtained at a surface of 1000 and 970 hPa from the initial data on wind fields for March 30–31, 1991.

As follows from Figs. 2 and 3, the developed model is well applicable for simulation of aerosol transfer and sink in the Siberian region: undesirable negative values are absent; aerosol transfer occurs in a different way depending on real distribution of wind fields at different points of the Siberian region (the direction of transfer is mainly meridional in the Southern Siberia and along parallels in the northern part of Siberia); one can see a difference in altitude distribution of concentration fields caused by regard for aerosol convective motion and sedimentation rate.

ACKNOWLEDGMENT

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