MODELS TO DESCRIBE METEOFIELDS AND FIELDS OF CONCENTRATION OF GASEOUS AND AEROSOL IMPURITIES IN SIBERIAN REGION

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Received January 16, 1997

The paper presents a study carried out under the project "Aerosols of Siberia" to create a complex system of mathematical simulation of atmospheric processes and ecological monitoring for Siberian region. The system includes meteorological data acquisition system, model of transfer of gaseous and aerosol impurities, the database "Aerosols of Siberia." The system efficiency was demonstrated in numerical experiments.

1. INTRODUCTION

At present the complex system of mathematical simulation of atmospheric processes and ecological monitoring to solve the problems of environmental protection, and expert estimations of anthropogenic influence is being developed under the project "Aerosols of Siberia".[1]

This system includes: a meteorological data acquisition system, model of the transfer of gaseous and aerosol impurities, the "Aerosols of Siberia" database.

Basic components contained in the complex system (regional models of the atmosphere and impurity transfer, meteorological data acquisition system) is described in Refs. 2–4.

Important component of this system is the data of measurements of both meteorological fields and gaseous and aerosol impurities. To obtain a complete pattern of pollution from the measurement data at separate points it is necessary to develop algorithms for processing this type of data.

At present the database including all this components using a concept of complex processing of data of meteorological and aerosol information and experience in the development of the meteorological data acquisition[3] system is creating.

2. DATABASE

To carry out a numerical experiment it is important to create and provide access to the observation database. The "Aerosols of Siberia" database consists of two basic components: the data archives and software to create this archives based on observational data, information control, support, access, sorting, graphic visualization and friendly interface. To develop the software the programming language *C* is used.

At present the archives with the data on aerosols has been prepared, the above modules are programmed and debugged. Because the study of transformation, transfer, and flow of aerosols requires knowledge of meteorological information, it is necessary to develop a meteorological data (both observations and results of their analysis) acquisition system connected with the "Aerosols of Siberia" database to reconstruct meteofields of the region under study with a sufficient accuracy.

We will briefly describe the structure of the archives containing the data on aerosols and meteorological elements.

2.1. Meteorological information archives

A review of modern meteorological data acquisition systems and main databases is presented in Refs. 2 and 6. It is clear from the review that at present most complete database is the database described in Ref. 8. This database has been compiled under the joint project of National Centers of Environmental Prediction of the USA (NCEP USA) and National Center for Atmospheric Research of the USA. The base includes both the data of observations and fields for all the Globe since 1957 to 1996 analyzed with a version of the operative NCEP USA data acquisition system slightly simplified to save processing time (steps of spatial horizontal variables were doubled).

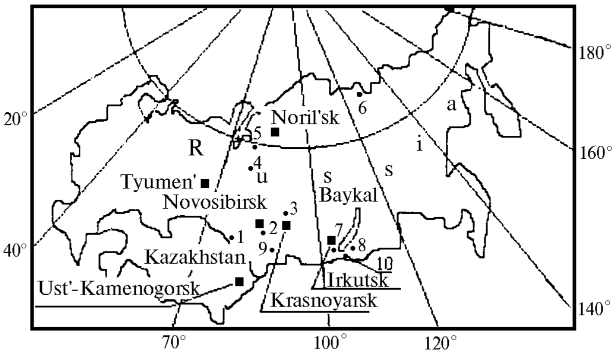
Taking this into account we chose this base to prepare necessary archives of meteorological data for the Siberian region.

2.2. Data archives "Aerosols of Siberia"

Aerosol properties are determined by its size spectrum, concentration, and chemical composition of particles. These parameters are the base for the data archives on aerosols of Siberia developed.[5] Besides, the archives includes the information on location and time of observation, information on devices used for observation, aerosol analysis method, results of statistical processing.

0235-6880/97/06 378-04 $02.00

The location and time of aerosol sampling in Siberia are presented in Fig. 1 and Table I. The small-volume and big-volume samplers were used for sampling and multi-stage and two-stage impactors to separate the aerosol particles by size were used too.



■ – large cities of region , ● – sampling locations
1 – Karasuk 2 – Klyuchi 3 – Pogorel'skii Bor 4 – Tarko-Sale 5 – Samburg 6 – Tiksi 7 – Listvyanka 8 – Tankhoi 9 – Ust'-Kan 10 – Mondy

FIG. 1. Locations of aerosol sampling in Siberia.

TABLE I. List of expeditions of aerosol sampling in Siberia.

Location of sampling	Start	Finish
Lake Baykal	15.06.91	10.07.91
Karasuk	05.02.92	04.03.92
Karasuk	20.08.92	03.09.92
Klyuchi	21.08.92	04.09.92
Klyuchi	12.03.93	24.03.93
Klyuchi	11.06.93	25.06.93
Lake Baykal	02.09.93	08.09.93
Klyuchi	01.09.93	08.09.93
NNTs	21.10.93	19.11.93
NNTs	04.01.94	18.01.94
Klyuchi	04.01.94	18.01.94
Barnaul	01.01.94	31.01.94
Klyuchi	10.06.94	01.07.94
Chany	10.06.94	27.06.94
Zav'yalovo	25.06.94	07.07.94
Barnaul	10.06.94	22.06.94
NNTs	24.01.95	07.02.95
Klyuchi	24.01.95	07.02.95
Klyuchi	10.06.95	26.06.95
NNTs	10.06.95	24.06.95
Krasnoyarsk	14.06.95	18.06.95
Ust'-Kamenogorsk	29.07.95	24.08.95
Klyuchi	18.08.95	02.09.95
Altai	10.10.95	20.10.95
Klyuchi	28.11.95	28.12.95
Krasnoyarsk	28.11.95	12.12.95
Tyumen' region	10.01.96	28.01.96
Klyuchi	05.06.96	30.06.96
Sinemor'e	07.07.96	28.07.96
Sinemor'e	29.08.96	10.09.96

The samples were analyzed, on the whole, with the method of X-ray fluorescence analysis. Partly the data were analyzed using neutron-activation method. The methods of ion and gas-liquid chromatography were also used. Table II presents the list of chemical elements determined by different methods and already processed by the present moment.

TABLE II. Chemical composition of atmospheric aerosols.

Methods of analysis	Component	Element
Neutron-activation analysis	Multi-element composition	Ag, Ba, Cr, Cu, Fe, Mo, Nd, Al, V, Mn, Eu, Sb, Na, Sc, Cd, Lu, Yb, Hf, Rb, Au, Br, Cs, W, Th, As, Ca, Cl, Co, La, Ni, Zn, K, Ti
Atomic adsorption AA	Multi-element composition	Na, Al, Ca, V, Mn, Fe, Co, Ni, Zn, Cu, Ag, Cd, Sb, K, Be
Atomic emission AE	Multi-element composition	Mg, Al, Ca, V, Cr, Mn, Fe, Ni, Cu, As, Ag, Cd, Sb, Ba, Au, Pb, Be, Si
X-ray fluorescence analysis	Multi-element composition	Ca, Sc, Ti, V, Cr, Mn, Fe, Ni, Cu, Zn, As, Br, Rb, Sr, Y, Zr, Pb
Ion chromatography	Ion composition	SO_4^{2-}, NO_4^-, F^-, Br^-, Cl^-, HCO_3^-, Ca_2^+, Mg_2^+, K^+, Na^+, NH_4^+
Gas-liquid chromatography	Carbon	Organic Inorganic
Analysis of individual particles		Al, Si, Ca, S, Fe, Ti, Pb, Cl

Such statistical properties as: geometrical mean, root-mean-square deviation, enrichment coefficient were calculated for every measurement period for the chemical elements from Table II. Moreover, the correlation and factor analysis of the element concentrations was carried out.

In future we propose to fill this archives with the observations from other missions to use jointly the unified archives.

3. METEOROLOGICAL DATA ACQUISITION SYSTEM

The system for meteorological data acquisition developed at the Institute for Computer Technologies SB RAS consists of the following units:

- numerical (objective) analysis of observational data,
- prediction by mathematical models of the atmosphere,
- initialization of the initial fields of geopotential and wind,
- interpretation of results.

Note, that the recording system is developed on the basis of the conception of unit substitution. The system includes, in addition to the main menu, the menu for control of numerical experiment process, various variants of the analysis procedure, initialization, versions of prediction model, etc.

Numerical experiments to study the properties of this system are described in Ref. 3. The grid used in this experiment is centered at Novosibirsk 26 × 22 × 15 with a 300 km step horizontally for 15 levels (1000, ... , 10 mB). As was in Ref. 4 the side boundary conditions with recording of the information on tendency of geopotential near the side boundaries and assignment of the other fields using the data on 12-hours prediction of the National Meteorological Center of the USA (now NCEP USA) were used.

Numerical experiments showed the good efficiency of the system developed. So, the complete step of the three-dimensional multi-element analysis of isobaric surface height and wind with the initial processing of the initial data and medium order of the normal equation set solved for every box equaled 100 takes about 30 min on an IBM PC-486, and the prediction on 12 hours takes about 20 s.

4. MODEL OF IMPURITY TRANSFER

Mathematically the process of passive impurity transfer is described using the following equation

$$\eta_t + \mathrm{div}(U\eta) + L\eta = D\eta + F.$$

In this equation η is the concentration of aerosol substance migrating with the air flow; U is the air particle velocity vector; L is the operator describing local transformations of impurities; $D\eta$ is the diffusion term, and F describes a substance source. This equation is solved by splitting method employing monotonic difference schemes at every splitting step.[7]

To study properties of the model developed actual meteorological data obtained with the meteorological data acquisition system described above the methodical computational experiment with three simulated emissions to the atmosphere was performed. The grid with a 30 km step (251 × 211 × 19 grid points) was used in the transfer model. Figure 2 presents the fields of daily transfer of aerosol concentration at the surface of 850 mB pressure every 6 hours starting from March 30, 1991. Estimation of the experiments showed usefulness of the transfer model developed and of the acquisition system to study the transfer and flow of aerosols in Siberian region.

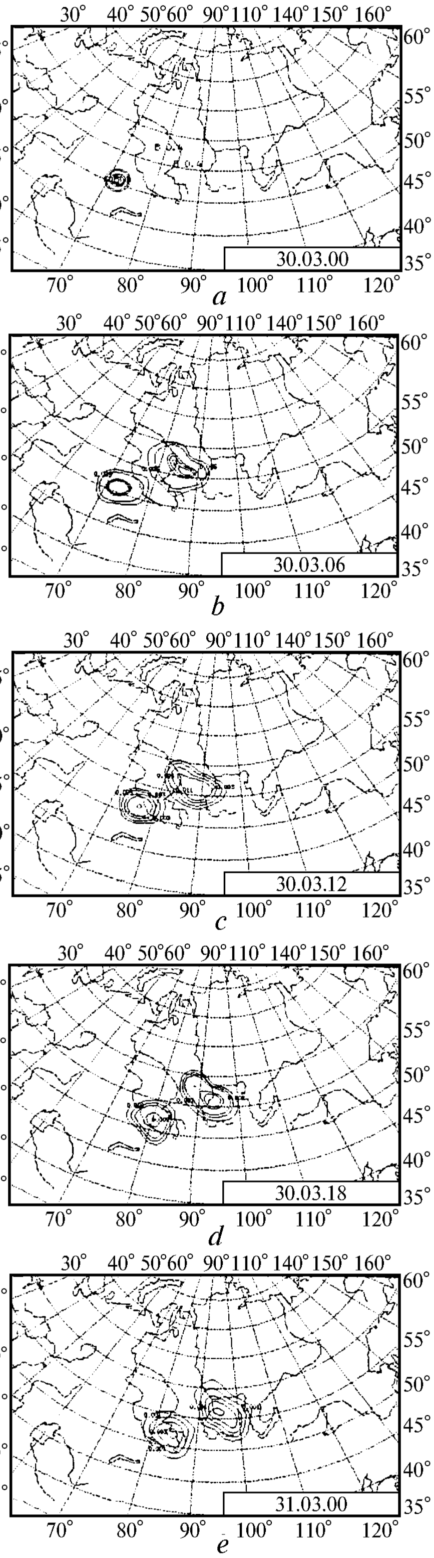


FIG. 2. Fields of daily transfer of aerosol concentration on the surface of 850 mB *pressure every* 6 hours *starting from March 30, 1991. Institute for Computer Technologies SB RAS.*

5. CONCLUSION

A verification of the meteorological data acquisition system and aerosol transfer model carried out showed the efficiency of the system and model developed. At present a numerical experiment with impurity transfer that uses actual data not only on the atmospheric processes, but on aerosol as well is prepared. The work being done to compile the database will help not only to provide feasibility of such experiments, but will give a possibility to expand the experiment by including the data of missions of other research groups.

The complex system being developed will allow various computational experiments by a scenario simulation of aerosol propagation to be performed.

ACKNOWLEDGMENT

The paper is supported by the Russian Foundation for Basic Research (projects Nos. 94–05–17–181 and 95–05–15581).

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