INCO
International Scientific Cooperation projects

FIRST ANNUAL REPORT
Covering the period from 01.10.2000 to 30.09.2001

ISIREMM
Integrated System for Intelligent Environmental Monitoring & Management
Contract Number: ICA2-CT-2000-10024

Project Homepage: http://www.ess.co.at/ISIREMM
Keywords: environmental monitoring, simulation modelling, environmental decision support
Title: Integrated System for Intelligent Environmental Monitoring & Management

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SUMMARY

ISIREMM addresses the problem of industrial pollution, and in particular, air pollution, and its effects on the human and natural environment. In a rapidly changing economic environment there are unique opportunities to include environmental concerns in the ongoing restructuring of heavy, and heavily polluting, industries as well as domestic energy use.

To do this efficiently, the project is using the results of a FW4 Environmental Telematics Project as the starting point, adapting it to the specific NIS conditions, and extends it with a number of advanced optical and acoustical monitoring methods developed at the NIS partner institutions into a new environmental management information system. The system is made ready to be tested in an implementation for the City of Tomsk, Siberia.

ISIREMM is designed for a three year period. The project is organised in a number of consecutive, overlapping phases of development, integration, and testing; at least two prototyping cycles are foreseen, resulting in two subsequent stages of the ISIREMM Demonstrator implementation and testing. The project phases are:

- Preparatory phase with requirements analysis, data compilation, and the adaptation of the ECOSIM software system used as the initial framework, and preparation of the new monitoring sensors to be used;
- Initial implementation phase concentrating on the testing and evaluation of the individual components;
- Second implementation and testing phase, concentrating on the evaluation of the integrated management information system;
- Comparative analysis, documentation, dissemination phase.

In the first year, covered by this report, the project has reached its first Milestone (end of preparatory phase, availability of design, requirements analysis, and basic data sets), and is well under way towards its second Milestone (end of initial implementation phase).

Following the initial kick-off meeting attended by all project partners and the definition of a detailed work plan for the first year, design, technical specification, and data compilation and processing efforts proceeded as planned, creating the basis for the first ISIREMM Demonstrator implementation.

The main results summarised in the first set of five Deliverables; they include design and specifications, data compilation, and the first steps towards the implementation of the ISIREMM Demonstrator. The first prototype release (R0.1) will be implemented in Tomsk in the fall of 2001. In addition, and in support of both project administration and dissemination activities, the project web server at http://www.ess.co.at/ISIREMM has been made operational and publicly accessible.
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Contribution of participants

WP 00: Project administration

ESS
ESS as project coordinator has organised the initial project kick-off meeting in Gumpoldskirchen Austria, during December 11-12, 2000. The minutes and main conclusions of the meeting are available on-line at the project web server, http://www.ess.co.at/ISIREMM.

The web server was installed early in the project and is being used both for public information and dissemination, as well as for project administration and the communication between project partners. A parallel ftp server (ftp.ess.co.at) was made available to the partners for data exchange.

IAO
The IAO team assisted to the Coordinator in co-ordinating the project activity of NIS Consortium Partners, firstly to this end the Russian language project Internet site was developed and opened (http://isiremm.iao.ru/russ/ISIREMM/ISIREMM.php). Special NIS partner’s management meeting was organized during the MODAS Conference in Irkutsk, 25-29 June 2001. Communications within NIS partners and assistance to the Coordinator in such communications had been organized, especially during preparation of progress reports, the preparation of review meetings, and compilation of cost statements.

ICMMG
Administrative activity is aimed at promoting better conditions of the work, coordination of the efforts inside the team and links with the partners

SRI
Participation in project management meetings, main activity was aimed at coordination of the efforts inside the team and links with the partners, and satellite data suppliers

BISIP
Participation in project management meetings, main activity was aimed at coordination of the efforts inside the team and links with the partners.

SILOGIC
Participation in project management meetings, main activity was aimed at coordination of the efforts inside the team and links with the partners.

NRD
Participation in project management meetings, main activity was aimed at coordination of the efforts inside the team and links with the partners, and regional data suppliers.

WP 01: Requirements analysis and data compilation

ESS
In WP 01 ESS has provided main guidelines for the data compilation (data requirements); the information compiled and distributed as the basis for the subsequent work packages is summarised in Deliverable D01.1, System Design and Technical Specifications. In addition, ESS has worked on the data processing and data analysis related to deliverables D01.2 and D01.3.

IAO
The IAO group performed jointly with NRD compilation of user requirements and constraints,
analysis of data requirements and data availability, compilation of the basic data sets for the initial implementation and testing of the software system. Jointly with the Coordinator (ESS) and with assistance of other Partners, mainly NRD, a consistent set of background data for the indicator development, the scenario analysis and model applications was chosen and prepared. All these data were organised into shared data structures in electronic form (text files, spreadsheets, data bases, and GIS data) and http and ftp access to the project information resources was provided for the Partners. Special attention was paid to preparation of additional layers for GIS of the Tomsk city and neighbouring regions. For example DEM were developed for the selected domains, which are the city suburbs (100km*100 km) and South of West Siberia (1400km*1400km), in the standard required by the MEMO model employed by SRI. The surface model is given as a rectangular grid built in Lambert Equal-Area Azimuthal projection. Altitudes of grid nodes are calculated on the base of digital map horizontals by the Kriging method.

ICMMG

As applied to the aims of the project, some aspects of interconnections between ISIREMM data base and the models developing by ICMMG have been examined. In particular, the joining versions of digital maps of relief, land-use categories, emission data, etc have been accommodated for our models. Two options have been designed for meteorological data and initial fields:

1) research one, when data come just from measurement sites and the reconstruction of initial fields has to be done with the help of data assimilation. This case is mostly typical for our conditions when the lack of data is common.

2) regular one, when all necessary data have been already prepared in the points of the model grid domain.

SRI

Activity of SRI group was aimed at elaboration of remote sensing data requirements and relevant data (satellite images of West Siberia) compilation for subsequent analysis. Remote sensing data are necessary for creating of current land-use maps and estimation, on the base of these maps, of ground surface parameters \( (Z_0, V_d) \). Also data of acoustic sounding, which provides with wind profile and inversion layer dynamic were compiled and requirements to them were elaborated.

BISIP

Procedures for retrieving required data on 3D distributions of polluting aerosol and gas atmospheric species from lidar sensors incorporated into the environmental monitoring being under development by the Institute of Physics group. These are:

– Estimating the emission power of local and distributed polluting sources.

– Validating the simulations of pollutant transfer.

– Refining the procedure of lidar monitoring of air pollution over an industrial center.

SILOGIC

Only a partial view of end user requirements related to displaying and presentation of data could be collected. No finalised version of the corresponding deliverable documents could be used. Hence, direct discussions for first survey and synthesis of user needs and technical requirements have been initiated.

Nevertheless, the overall progress of the work has not been significantly affected; synthesis of user needs and technical requirements have been initiated.

The technical architecture agreement includes the usage of LINUX servers as main platform for the system, and of MySQL, a royalty-free, yet efficient, open and portable database management system. The Internet is used as a federating communication means. Web presentations are one of
the required components of the system. In particular, different displays of time series of data are considered as a priority.

**NRD**

The following local data important for modelling and for air quality determination were gathered: meteorological data sets from three State meteo-stations located at Tomsk Region as well as air quality measurement data sets from sixth points of Tomsk city for the whole 2000-year, updated industrial emission inventory for Tomsk city, updated Geo Information Systems (GIS) (electronic maps) for the three chosen territories. According an order of the Regional Administration Head this work was done with participation of relevant Regional organizations responsible for the environmental issues. Namely, meteorological and air quality data preparation was performed by the Regional Unit of the State Committee on Meteorology and Environmental Monitoring, industrial emission inventory was prepared by the Regional Unit of the State Committee on Ecology and GIS were prepared by State enterprise Tomskgeomonitoring.

After compilation of the data sets they were transformed into electronic form and pre-processed into Excel format with participation of the IAO group (P 02). Also required for model initiation local characteristics such as atmosphere stability classes, categories of land use, etc., were retrieved from these data sets with their participation. Pre-processed data sets as well as the retrieved characteristics were delivered to the Project coordinator (ESS, P 01) and placed at the Project WWW-site http://isiremm.iao.ru/.

Digital maps in the ArcView GIS 3.x format were prepared for Tomsk city itself, Tomsk city and neighbouring suburbs and West Siberia by the Tomskgeomonitoring enterprise and for the West Siberia territory an available digital map DCW in scale 1:100000 was used.

The city map is provided with usual and additional layers. 22 typical cartographic layers were prepared by Tomskgeomonitoring, while 9 specific layers with information supporting modelling efforts were prepared by the IAO group. Digital maps with all layers were passed to the project coordinator, files required for modelling support are placed at the project ftp.

Data from four meteorological stations in the vicinity of Tomsk (Bogashevo, Kozhevnikovo, Tomsk South and IAO SB RAS (East), the coordinates are fixed at the digital maps) were gathered to provide the ISIREMM Project with required background. Among gathered for the whole 2000-year data are wind velocity, temperature, humidity, pressure, cloud characteristics, etc. These data were transformed into electronic form and were prepared as EXCEL files. More general meteorological characteristics were determined in cooperation with the IAO group (P 02). These are stability classes and mixing heights. For their determination data from meteorological balloons, launched at Novosibirsk aerology station were used.

All pre-processed meteorological data were passed to ESS group (P 01) and placed at the project ftp thus giving all partner an access to it.

Emission data required for air quality modelling include industrial point sources of emission (mainly stacks), linear sources of emission (city street segments with heavy traffic), area sources of dust and industrial emissions and VOCs point and area sources were prepared by the Regional Unit of the State Committee on Ecology in unknown coordinates. Their positioning at the city digital maps was performed with IAO groups. General pattern of all sources of emissions in the city is shown on the Fig.1.
To provide the system developed with relevant supporting information main industrial sources of pollution in the city were chosen and described in the file **Point sources of emission**. Closely placed small sources of industrial emissions were grouped into 12 area sources. Relevant file **Area sources** of emission is prepared as well.

Special work was organized jointly with IAO group to determine characteristics of linear sources of emissions. To this end heavy loaded with traffic streets of Tomsk city were chosen. To determine characteristics of the road segments (linear sources) two series of measurements (March and April-May) were performed. Processing their results is summarized in the file **Linear sources of emission**.

To provide the photo-chemical modelling block of the system with data sources of VOC where chosen from the whole set of polluting the area sources of VOCs and grouped into the following two sets: point and area VOC sources. Relevant file **Area and point VOC sources** was prepared.

To provide modelling efforts with reference air quality monitoring data based on measurements performed by the Regional Unit of the State Committee on Meteorology and Environmental Monitoring were prepared and pre-processed. Results of measurements of chemical compound concentrations at 6 points of the city during 2000-year are prepared in the form providing with information on month, date and hour of measurement and complimentary characteristics are temperature, wind direction, wind speed and atmospheric phenomena. Wind direction and atmospheric phenomena are described qualitatively.

To provide the system with possibility to determine number of Tomsk citizens exposed to action of unfavorable air pollution influence during especially heavy situations data on the city population territorial distribution were gathered and pre-processed as well. These data form additional information layer for the digital map of Tomsk in ArcView GIS.
**WP 02: Software adaptation and implementation**

**ESS**

ESS has worked on the adaptation of the AirWare system including the client-server extension developed in the ECOSIM (Environmental Telematics) project.

Deliverable D02.1 (Implementation Report) describes the implementation of the first prototype of the ISIREMM Demonstrator, the data used, and the range of functionality currently supported in the initial release.

**IAO**

Within WP 02 IAO team efforts were concentrated mainly on pre-processing the data compiled in WP 01 for the system and on developing GIS-applications and meteorological databases of the city and region based on WP 01 results. It includes development of GIS-applications and meteorological databases of the city and region based on WP 01, compilation of applicable national and regional legislation and organization of online connection with the mobile and stationary sensor stations. Relevant databases are prepared. Software supporting online connection is developed and tested for the TOR-station, which is an IAO set of stationary sensors and relevant site is open in Internet (http://meteo.iao.ru/?lang=eng).

**ICMMG**

The capabilities of the ECOSIM/AirWare system have been studied to accumulate the experience on designing the systems for ecological forecasts and to be oriented in the frames of the project. The preparation has been made to adapt our modelling system for work with data and partners in ISIREMM. The LINUX-server-controlled local laboratory net has been organized.

**SRI**

The SRI team input here concerns with into development of GIS-applications, namely with retrieving information on surface characteristics from satellite images. Adopted way to estimate surface roughness (and dry deposition velocity) and land use categories is based on analysis of passive sensing data i.e. reflecting capability of ground surface. To build land cover maps there have been processed the images of Tomsk and its environs. The images were received from the RESOURCE-01 N 3 satellite on July, 4, 2000 (MSU-E scanner) and on May, 5, 2000 (MSU-SK scanner). Image processing was made by ERDAS Imagine software. The images were processed in 2 stages: primary processing and thematic classification. Primary processing included geocoding, filtration and brightness normalization. Classification consisted in transformation with the usage of Supervised Classification. The image from MSU-SK scanner (35 m resolution) has been used as an input file. To create the input Signature File there has been applied the ground cartographic information (1:1 000 000) given by the colleagues from Tomsk (IAO). This information contains the following coverages: hydrographic objects (lakes, rivers, watersheds, channels); populated areas (towns, settlements); railways, highways, roads etc.; vegetation (forests). Possessing these cartographic data water objects, large populated areas, forests, vegetation in Tomsk Region are identified. At present time the work on image identification and analysis is being continued to provide partners with detailed land use classification..

**BISIP**

Software for lidar data processing is designed to provide the system with characteristics retrieved from lidar measurements. It includes programs to control the lidar system while measuring; programs to retrieve distributions of atmospheric aerosol and gas components along a sounding path by lidar data; database of lidar sounding; program package to map pollutant fields.

The control programs are adapted to the specifications of the lidar systems used to monitor pollutants. With this, the unique format of output data files is conserved. The body of a single
measurement file is about 8.5 K. The body of lidar data for a single measurement series according to items 2.1 to 2.3 is 200 to 500 K. Aerosol parameters are measured by the multi-frequency sounding method. The respective program implements the algorithm for solving a set of lidar equations by the optimal linear estimation method to close the set. Concentrations of gaseous species are measured by the differential absorption lidar method while sounding at two wavelengths on and off the absorption band of a species studied. The lidar database is formed by the package ACCESS. Digital pollutant maps superimposed on a city electron map are constructed to visualize the data. The information on the structure of lidar data files has been transferred to IAO.

**WP 03: Remote sensor development**

**IAO**

Within **WP 03** IAO activity was devoted to modernisation of the set of stationary remote sensors (lidars and photometers) intended for environmental monitoring of the atmosphere over Tomsk City, to design and construction of mobile units equipped with remote and local sensors of meteorological quantities as a means of collecting supplementary data in support of stationary monitoring and to development of the software tools for real-time data acquisition, processing, and preliminary analysis.

The aerosol lidar LOZA–M is scanning system to be used for environmental monitoring of the atmosphere over Tomsk City. It has been modernized compared to that previously used to improve positioning characteristics. Both lidar recording and control system which was developed are now based on an PC. A device of digital recording of lidar returns was set in the standard of this computer and was built directly in a processor. Basic design specification of the LOZA-M lidar are: operation range 5-7 km, wavelength 0,53 mkm, spatial resolution 7.5 m, angular resolution 10 min of arc and mass 70 kg. Each sounding step is organized into an individual data file. A serial number is assigned to this file which comprises a shot data sheet with measurement time and other specifications. During the experiments in synchronism with the lidar measurements, the visual information was recorded on a video with the TV–camera. Thus some supplementary data were obtained for subsequent interpretation of the results of sounding.

Modernized Raman lidar is based on the airborne lidar M2M, which proved its reliability in plenty of field works and is aimed at remote determination of SO$_2$ concentration in gas mixture leaving industrial stacks. Optico-mechanical block is not changed, which allowed us to use the same laser, frequency doubler and telescopes. Registration block is subjected to modernization and now is adjusted to spectral separation of the signals required for SO$_2$ concentration measurements. Modernized Raman lidar should allows one to arrive to 75 mln$^{-1}$ minimal detectable SO$_2$ concentration at 15 minutes measuring time.

Modernized panoramic (all-sky) photometer aimed to monitoring industrial plums and cloud patterns consists of an opto-electronic modulus placed on the roof of the IAO building and remote registration and pre-processing block. The opto-electronic block employ two video cameras Digital8 Sony TRV730 to get images either all sky hemisphere or its chosen parts. The registration and pre-processing block allows to get panoramic images 576×576 pixels and localized images 768×576 pixels. Registration can be done in the continuous regime (25 frames/sec) or in the single frame regime (0,2 sec per frame). Results of current sky observations are presented in Internet (http://nebo.iao.ru/).

Mobile station “Atmosphere-K2” equipped with remote and local sensors of meteorological and air quality quantities as a means of collecting supplementary data in support of stationary monitoring is designed and developed. It includes an meteorological system with a meteorological mast, an aerosol complex, a gas analysing complex, a registration system, provided with ADC and radio modem. The station allows one to measure the following characteristics: aerosols disperse content, aerosol scattering and absorption coefficients, pressure, temperature, humidity, wind
velocity and direction, solar radiation, ozone, NO, NO\textsubscript{2} and SO\textsubscript{2} concentrations. Software supporting real time communications with the system server is currently in process of design.

**ICMMG**

The principle tasks have been examined: how to fit and assimilate inhomogeneous data into the models in such a way that the shock-effects to be avoid. For the aim of the project the efficient methods of real-time data assimilation are needed. It is necessary to provide an agreement in resolution in the model and data as well. Starting from this point, the analysis of the state–of-the-art on data assimilation has been made. The comparison studies on estimation of observability domains of measuring sites and informative quality of data have been made with the help of numerical experiments. In accordance with our considerations, if measured data are used together with models for reconstruction of the state functions, then their common informative quality is essentially higher even if the set of observations is comparatively small. As a consequence, the fast data assimilation procedure, which is specially adjusted to assimilate volumetric and plane remote sensing data has been designed on the base of variational principle (see WP05).

**SRI**

The SRI sodar complex has been upgraded: antenna complex mounting on the grown suitable for measurement performance was done and receiving block was upgraded. Two antennae have been placed in such a way that their horizontal rotating axes allow to direct one of them to north or south, the second – to east or west. The third antenna is intended for estimation of vertical wind velocity and for this reason it is directed along vertical line. For stable arranging of the antenna concrete square grounds (700*700*200 mm) were poured over the prop. were placed in them. The second stage of works is connected with modernization of the system for sodar data processing in real time mode. To perform operative control of atmosphere and to make prognosis of air parcels motion it is necessary to process the acoustic sounding data immediately during measurements carrying out. To provide such regime the cycle of the reflected signal passing from the measuring block's input chains to display (or printer) should be fulfilled earlier than that of acoustic signal passing from emanator to sounding upper point and returning to the receiver. In the “LATAN-3” acoustic locator sounding begins from 30 m and thereby the time of initial signal receiving is equal to \( \sim 0.1 \) sec.

One of the principal problems currently under study is exporting acoustic sounding data to the GIS in the real-time mode. With this in mind, a proper structure of the database has been designed and implemented to meet exacting requirements of preparation procedure dealing with data used in contaminant transport model. At this stage the following works have been performed: the structure of an open database has been created; a channel capable of real-time transmitting huge amounts of information to the GIS has been thoroughly tested; algorithms corresponding to different time intervals (from 1 to 10 min) have been developed and realized; graphic user interface in the form of a window depicting vertical wind profile has been developed.

**BISIP**

Two following lidar systems were prepared to participate in project performance:

Multi-purpose mobile lidar station MLS is designated to measure concentrations of aerosol species and polluting gaseous components near industrial enterprises. Aerosols are sounded in the visible. Concentrations of polluting gases are measured by the differential absorption lidar method over the mid-IR by using a tunable TEA CO\textsubscript{2}-laser. The lidar is mounted in a car van.

Omnidirectional (panoramic surveying) lidar station is created to refine methods for lidar monitoring of atmospheric pollutants over the scale of an industrial center, for mapping of spatial pollutant fields, and detection of polluting emissive sources. It includes two lidars. Their specifications are close to the aerosol and gas channels of the MLS. A lidar site for panoramic surveying is equipped on the building of the Institute of Physics, where routine lidar observations of
polluting impurities of the city air basin are made.

**WP 04: Baseline simulations**

**IAO**

Within **WP 04** investigations of air quality related to the meteorological and land use features of the city of Tomsk are performed, a set of meteorological scenarios leading to bad environmental situations were determined from historical data thus giving the background for modelling applications. In particular, air quality data from WP01 were investigated with relation to the meteorological and land use features of the Tomsk city, which lead to a set of representative meteorological scenarios for the area. Currently the modelling of scenarios for the chosen dates is performed.

**ICMMG**

A series of numerical experiments has been made with the help of our 3D numerical model of hydrodynamics of meso-regional scale (see WP07). The model has been used in the research mode (see WP01). It means that the initial state has been reconstructed from the limited set of input data. The daily behavior of atmospheric circulation has been simulated. The main attention has been focused on the convective processes, which might be responsible for accumulation of the pollutants in the particular subdomains. The results of the scenarios have been transmitted to the partners P02 to be analysed.

**AUT**

The air pollution model system used in the frame of ISIREMM was developed AUT and represents one of the most widely utilized European model systems developed for the description of local-to-regional dispersion and chemical transformation processes1 (Moussiopoulos, 1995b, Moussiopoulos et al., 1993, Kunz and Moussiopoulos, 1995). In its present version, the model system takes fully into account the manifold interactions between the various scales influencing the pollution patterns in the airshed considered and comprises of the models MEMO and MUSE.

Wind flow will be simulated with MEMO, one of the core models of the European Zooming Model (EZM) which belongs to the family of models designed for describing atmospheric transport phenomena in the local-to-regional scale. EZM was developed for the refined modelling of transport and chemical transformation of pollutants in selected European regions in the frame of the EUROTRAC subproject EUMAC (therefore its previous name EUMAC Zooming Model). In the meantime the EZM has evolved to be one of the most frequently applied mesoscale air pollution modelling systems in Europe. Thus, it has already been successfully applied for various European airsheds including the Upper Rhine Valley and the areas of Heilbronn, Basel, Graz, Barcelona, Lisbon, Madrid, Milano, London, Cologne, Lyon, The Hague and Athens2.

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Moussiopoulos N., Flassak Th., Sahm P. and Berlowitz D. (1993), Simulations of the wind field in Athens with the nonhydrostatic mesoscale model MEMO, *Environmental Software* 8, 29-42.


MEMO is a physically complete non-hydrostatic mesoscale model which allows performing multiple nested grid simulations. Within MEMO, the conservation equations for mass, momentum and scalar quantities such as potential temperature, turbulent kinetic energy and specific humidity are solved. The governing equations are solved in terrain-influenced coordinates on a staggered grid arrangement allowing for non-equidistant grid spacing in all directions.

As an important feature of MEMO, conservative properties are fully preserved within the discrete model equations. The discrete pressure equation is solved with a fast elliptic solver in conjunction with a generalised conjugate gradient method. Advective terms are treated with a total-variation-diminishing scheme. Turbulent diffusion is described with an one-equation turbulence model (conservation equation for the turbulent kinetic energy and algebraic equation for the mixing length). At roughness height similarity theory is applied. The radiative heating/cooling rate in the atmosphere is calculated with an efficient scheme based on the emissivity method for longwave radiation and an implicit multilayer method for shortwave radiation. The surface temperature over land is computed from the surface heat budget equation. The soil temperature is calculated by solving an one dimensional heat conduction equation. At lateral boundaries generalised radiation conditions are imposed.

Air pollution in the Tomsk area will be studied with the multilayer photochemical dispersion model **MUSE**, which is one of the core models of the EZM. The EZM system is a complete system for simulating the wind flow and pollutant transport and transformation in the mesoscale as described previously. Main modules of the EZM are the nonhydrostatic mesoscale model MEMO (see above), the photochemical dispersion model MARS3 and the multilayer dispersion model MUSE4 which was developed as a simplified version of the 3-D dispersion model MARS.

MUSE is a multilayer Eulerian photochemical dispersion model for inert and reactive species in the local-to-regional scale. The atmospheric boundary layer is divided into individual layers; the thickness of each layer is allowed to vary in the course of the day in order to adequately simulate the dynamics of the atmospheric boundary layer. In this study five layers have been used. A shallow layer adjacent to the ground is defined for the proper simulation of dry deposition and other sub-grid phenomena. The upper limit of the second layer is defined at a height equal to the half of the mixing height. The latter is described by Deardorff's prognostic equation which was shown to lead to realistic results when the variation of the mixing height with time is strongly influenced by surface heating. The upper limits of the third and the fourth layer are defined by the lower and upper limit of the entrainment zone. The top of the upper layer, which serves as a reservoir layer, is fixed to an altitude of 3000 m.

Advective transport is described with the scheme of Smolarkiewicz. The average wind speed in

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3 Moussiopoulos N. (1989), Mathematische Modellierung mesoskaliger Ausbreitung in der Atmosphäre, Fortschr.-Ber, VDI Reihe 15, Nr. 64, VDI-Verlag, Düsseldorf.


each of the five layers is calculated by integrating the fluxes of the corresponding layers of the fully 3-D wind field computed by the model MEMO.

The differential equation system in MUSE is solved with a backward difference solution procedure, i.e. by applying the Gauss-Seidel iteration scheme. Because of the nature of this semi-implicit algorithm, vertical diffusive transport and chemical transformation of pollutants have to be treated separately. In view of the feasible error caused by splitting the operators associated with vertical diffusion and chemistry, the justification for this separate treatment should be controlled by the aid of selected applications of the implicit version of MARS.

In order to proceed with model calculations in the Tomsk area, an appropriate configuration and set-up should be made. For this reason, a number of preparatory actions were undertaken from the modelling point of view during the first year of the project, in order to set-up and test the software of the MEMO and MUSE models and to screen and provide with the necessary input requirement information to the data providing partners.

Following the tasks planned according to the ISIREMM Technical Annex, AUTH/LHTEE compiled the air quality model framework as described above and made various tests, in order to be able to proceed with the simulations during the next reporting period. Although simulations were scheduled to start during the first project period, it was proven to be more efficient to invest more time in the preparations of the modelling infrastructure. This, however, does not influence the overall progress of the project work.

AUTH/LHTEE provided with the necessary information to the partners involved in the modelling task. Due to some delays in the response of these partners, AUTH/LHTEE could not use man-month resources allocated as internally planned, and had to change the time frame of performing the simulations as a result of internal personnel reallocation. Nevertheless, tasks will continue according to Technical Annex. It should also be noted that, following the experience of the ECOSIM project, upon which the ISIREMM architecture is based, AUT/LHTEE investigated new features like the introduction of XML structures in the modelling module, in order to make it compatible to the ISIREEM architecture.

SRI

Mathematical model of the atmospheric pollution transport relating in simple form meteorological and land use characteristics of an area under study is suggested as a set of equations for mass concentrations of species. After its simplification by mean of averaging over the vertical axis taking into account the boundary conditions at \( z=z_0 \) and \( z=H(t) \) it became 2 D-problem. Namely equations derived are suggested for subsequent usage on the base of historical data.

BISIP

During the first year of the Project execution, the investigations have been carried out to estimating the power of emissive sources by lidar sounding data, estimating the errors in lidar-measured power of dust emissions and elaboration of procedure to measure power of stationary point gas sources. In spite of the fact that design of procedures for lidar monitoring and algorithms for data processing and retrieving information on pollutant sources and pollutant transport in atmosphere mainly belong to subsequent task it is of importance for this one. It allows one to provide a set of baseline simulations with opportunity to verify modelling results by means all available techniques. Also it allows one to verify officially reported to controlling organization data on quantitative

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characteristics of industrial emissions. In more details this activity is described in the next work package description.

**NRD**

Here NRD activity was aimed at providing both historical and current data required for baseline simulations and at development a set of representative scenarios based on historical data. To this end air quality measurements during 2000-year were analysed, 12 "bad" cases belonging different seasons were determined and results were passed to P 02 for subsequent synoptic description.

**WP 05: Monitoring data integration**

**IAO**

Here the activity was focused adaptation of the set of simulation models of the original ECOSIM/AirWare system to direct usage utilise volumetric and planimetric data obtained from optical remote sensors (lidars) and from satellite imagery, relevant data assimilation methods for effective use of of such measurements were developed and tested during special campaign.

The first step of activity comprise the development of modelling software to directly utilise data from the remote sensing instruments performing 3D atmospheric parameter measurements with on the basis of WP 04 and the parallel WP 07 intermediate results, an optimal regime of remote sensor operation (frequency of measurements, averaging period, etc.). A simplified model for air quality prediction on the base of the remote sensor data is suggested, in which nonstationary one-dimensional boundary layer model is employed for wind and turbulence dynamic characteristics determination. In the simplified model current meteorological data (temperature, humidity and turbulence) are used as boundary conditions, which allows one to get operative data for city atmosphere pollution. It is shown that such approach can not be used for surfaces with non homogeneous surface temperature and orography. To test the model forecasted wind and turbulence data were used for numerical prognoses of Tomsk power station GRES-2 plums transport above the city. The Lagrange trajectory stochastic model was used for numerical simulations. Lidar measurements of the plum were performed during 23 April –11 May 2001 to verify model predictions. The LOZA-M lidar scanned 22 degree sector with the GRES-2 stack in it, the distance to the stack is 3 km. It provides 3-D industrial aerosol backscattering coefficient distributions, which were used for the model validation.

The second simple model developed is aimed at determination and prognoses of hazardous UV B radiation (280<λ<315nm) at selected area (city and its nearest suburbs used as recreation place) on the base of its local measurements. Aerosol and cloud distribution in atmosphere determining amount of UV radiation reaching the surface is planned to be retrieved from aerosol lidar and all sky photometer measurements. Algorithms based on the Monte-Carlo method are time consuming and bulky. The suggested simplified approach is based on the Eddington method. Performed study shows that this approach can be used both for cloudiness and cloudless atmosphere

**ICMMG**

Some aspects of the use of specific remote sensing data from the ISIREMM database have been considered. These data can be exploit for the reconstruction of the state functions with the help of the methodology of combined use of the models and data in assimilation mode.

The new fast version of data assimilation technique has been developed. It follows our methodology that combines direct and inverse modelling procedures. The idea of the approach is as follows. The goal is to construct an efficient algorithm of joint use of two basic elements of investigation: model and data. The problem considered can be solved with the help of variational approach and splitting technique. The generalized quality functional is introduced in the form

$$
\Phi^k(\hat{\varphi}) = 0.5 \left( \alpha_1 (\hat{\varphi}^T M_1 \hat{\varphi} )_{D_1^p} + \alpha_2 (\hat{\varphi}^T M_2 \hat{\varphi} )_{D_2^p} + \alpha_3 (\varphi^T M_3 \varphi )_{D_3^p} + \alpha_4 (\varphi^T M_4 \varphi )_{R_4(\hat{D}_4)} \right)^h
$$
\[ + [I^h(\phi^h, \phi^0, \phi^r)]_{\partial t}, \]

where \( M_i, (i = 1, 4) \) are weight matrices, \( \alpha_i \geq 0, \sum_{i=1}^{4} \alpha_i = 1 \) are weight coefficients,

\( h, h \) denotes transposition and discrete analog,

\[ \int_{D_i} (\frac{\partial G}{\partial t} + G(\phi^0, \phi^r) - \phi^r) \phi^* dD dt = 0 \]

is the variational form of the model, \( \phi^* \) is co-state function, that is generalized Lagrange multiplier. In this case, the model plays the roles of restriction to the state function and connection between model parameters and the state functions. The inner product in (2) is defined from the energy balance of the system. The first four terms in (1) are the corresponding discrepancy functionals.

A minimization functional problem with respect to the components of the vectors \( \rho^0, \rho^r, \rho^e \) is formulated. The set of computational algorithms is obtained from the stationary conditions for \( \Phi^h \) to variations of the components of vectors \( \phi^0, \phi^r, \phi^e, \phi^r, \phi^e \) on the grid domain \( D_i^{h} \). As a result of the problem’s solution, functions \( \phi^0, \phi^r \) describe the space-time system behavior; the function \( \phi^e \) shows the model errors estimated with respect to data \( \Psi^m \).

A variational principle is the base for all algorithm constructions. The main inverse modelling procedure, that we usually use for data assimilation, leans upon technique of adjoint problems and sensitivity functions generated by (1)-(2). Here we describe the “light” version of assimilation algorithm. To this end a variational principle for (1), (2) and splitting technique are used. The splitting method as a method of weak approximation with fractional steps in time is applied. It is supposed, that data of measurements and errors of the model are taking into account at the final stage of splitting scheme at each time step. We show how the observed data can be involved in modelling process as soon as new information becomes available. The algorithm of the solution is slightly modified one as compared with the realization of corresponding splitting stage without assimilation. Parameter \( \alpha_i \) is determined, which can be used for control the assimilation procedure. If \( \alpha_i = 1 \), the model ignores measured data, and if \( \alpha_i \to 0 \), the data are predominating in calculation of the state functions. Contribution of each element is defined in dependence on the degree of reliance in this component.

The algorithm for fast data assimilation is based on local optimum conditions for objective functionals in the framework of splitting technique that is used for the discrete form of the model. It is realized with the help of a direct modeling procedure that successively assimilates incoming data. The data are included by means of a quality functional at suitable splitting stages and corresponding time steps. The algorithm provides fast data assimilation and reconstruction of state functions with reasonable accuracy. It is more effective in a computational sense. Being combined with the main inverse modeling procedure derived from (1), it generates a good first guess for the solution of inverse problems.

To include the specific remote sensing data into the models of hydrodynamics, transport and transformation of pollutants with the help of the presented technique, it is necessary to describe algorithmically the operators of the models of observations. To this goal, the further collaboration with the partners IAO, SRI and IFNASSB is planned.

SRI

Mainly activity was aimed at integration of data coming from acoustic sounding and satellite remote
sensing. Here one of the main concerns is exporting acoustic sounding data to the GIS in the real-
time mode. With this in mind, a proper structure of the database has been designed and
implemented to meet exacting requirements of preparation procedure dealing with data used in
contaminant transport model. At this stage the following works have been performed: the structure
of an open database has been created; a channel capable of real-time transmitting huge amounts
of information to the GIS has been thoroughly tested; the algorithms corresponding to different
time intervals (from 1 to 10 min) have been developed and realized; a graphic user interface in the
form of a window depicting vertical wind profile has been developed. The user interface permits: to
scroll a sequence of diagrams, to modify scale and spacing of the sections and to perform
averaging procedure over time and/or vertical coordinate.

BISIP

Efforts were devoted to efficient integration of lidar measurements data, that is aerosol fields and
polluting gas concentrations into models. The procedure to compute power values of polluting
emissions is based on lidar measurements of concentration distributions of a polluting impurity at a
surface surrounding the polluting source and on calculations of the impurity flux difference at the
surface. With this, the wind velocity field is measured or simulated. The experimental scheme was
approbated under field conditions of determining the power of aerosol emissions at a potassium
enterprise of Soligorsk (Belarus). We have carried out the investigation of the spatial distributions
of dust mass concentrations over horizontal and vertical planes in the atmosphere above the
enterprise. Errors in power estimations depend on measurement accuracy of concentration
distributions over the jet section. Sounding schemes were designed to determine optimal
observational conditions.

The method to derive power of a stationary source of an impurity includes the measurements of
the integral of the concentration along an arbitrary jet section to subsequently multiply it by wind
velocity. Experiments are usually arranged so that a laser operating with pulse repetition rate \( \nu \) Hz
transmits \( N \) averaging pulses along a single sounding path, then after duration \( T \), required to
change the observation direction, one starts measurements along another path. The interval of the
observation directions should exceed the angular size of the probable jet location. The procedure
was elaborated to estimate magnitude of errors in jet power in dependence on distance from the
lidar. An attempt was done to create a procedure for lidar measurement of gas concentration
integral over the jet cross section on the base of the measured integrals of the concentrations
along the observation direction, which will not require any spatial resolution along the observation
direction. The transient character of a jet owing to large-scale atmospheric turbulence is taken into
account. The diffusion of a polluting impurity from real sources was computed according to the
procedures developed for 3-D modeling. The calculations were compared with real distributions of
pollutants by field lidar observations near emissive sources.

For a number of cases, emissive sources are transient. The procedure to compare lidar and
theoretical data for transient emissive sources will be commonly elaborated by the scientific groups
of the Institute of Physics and the Institute of Atmospheric Optics. Preliminary results of data
processing of comprehensive experiments show that the treatment of a finite threshold of impurity
detection by the lidar method is needed to adequately describe a field experiment.

NRD

Here the NRD group prepared regional base-line meteorological scenarios and relevant data in
form adapted for test runs of models.

WP 06: Client-Server Communication

IAO

Within WP 06 software supporting online connection of stationary sensor-stations with a server
was developed and tested. As an example the IAO Aerosol station Internet site
(http://aerosol1.iao.ru/index.e?lang=eng) is shown on the Fig.14. Here results of regular measurements of atmosphere aerosol characteristics as well as relevant meteorological characteristics performed at the Aerosol station are presented in real time regime. All software designed is based on the Internet technologies. Similar work was performed at the IAO TOR station. The software developed and tested will be used to support data transmission from the mobile sensor unit as well.

**ICMMG**

The laboratory server is organized for communication in the client-server mode. The server uses OS Linux

**SRI**

Work to employ Internet technologies for sodar-model data exchange has been started

**BISIP**

An attempt to organize remote access to the database archiving lidar measurement results is in process at currently.

**SILOGIC**

Survey and familiarisation with basic system data formats (Airware/ECOSIM), technical documentation and references as well as results of the different models to be used in ISIREMM.

Review of state-of-the-art of basic techniques used for time series analysis, including identification of patterns using smoothing or curve fitting techniques. It leads to considering different types of displays combing graphical and numerical information.

Implementation work conducted during the reporting period has covered first prototyping of generic-purposes applets. This shall allow for consultation and graphical representation of data and model results through HTTP. One of the objectives is to have portable code allowing usage of most navigators.

Sources of data to be considered for the design of the communication infrastructure have been reviewed together with IAO. Meteo data through TOR / Tomsk / and two other possible sensor-stations, 6 to 10 air quality stations, stations for point source emission, stations for area source emission and sensors for linear source emissions. Precise procedures, resources and number of stations is still to be refined.

**NRD**

Within this WP NRD activity is aimed at determination of system low-bandwidth remote user types and level of their access to the system, as well as at specification of their needs and their technical support.

**WP 07: 3D model development**

**IAO**

Here 3D model development main efforts were devoted to coupling 3D models for city and regional scale pollutant transport to monitor environmental impacts of an industrial center on neighbouring regions. To describe dynamical and thermal processes above the city the following 3-D mathematical model was suggested, in which the vertical turbulent diffusion coefficients are determined on the base of ”k-L” turbulence model, horizontal turbulent diffusion coefficient is assumed to be constant. Solar and long wavelength radiation fluxes were calculated according Albrext and Brent, while turbulent heat fluxes were determined on the base of Monin-Obukhov theory. This non hydrostatic model of lower boundary layer allows one to obtain detail pattern of circulation, thermal and humidity state of the system “atmosphere + underlying surface”. To initialise it adequately the one dimension non stationary model for atmospheric boundary layer
was elaborated.

The above model was used for simulation of pollutant transport in Tomsk city. Pollutant transport for 24 April was modeled and results were compared with local and remote measurements performed at the same time. Fig. 2 shows that agreement of simulated and measured characteristics is quite good.

Fig.2.

Here black domains are the maximal aerosol concentrations along the laser-sounding path, while blue domains are for the forecasted pollutant distribution.

ICMMG

The development of the new versions of 3D numerical model of hydrodynamics and pollutant transport are in progress.

Two types of models are designed: local-to-regional scales and regional-to-global scales.

The first type is focused on the study of the quality of the atmosphere in the city (Tomsk) and surroundings (WP04). The large-scale models of the second type are necessary to study the scales of interaction in the climatic system, when the Tomsk region plays the role as the source as the receptor of disturbances. They are also useful for estimation of the trans-boundary interconnection with the other regions and for evaluation of the risk/vulnerability domains. To these goals, the methodology is organized that is based on the direct and inverse modeling procedures, and sensitivity theory.

The models are written in the surface-following coordinates. The model of the first kind uses the Cartesian coordinates on limited area. The geographical coordinates are introduced in horizontal direction in the models of the second type. A hybrid coordinate is used in the vertical that implies the decomposition of the domain into two parts. The models are closed with boundary conditions. The fluxes of substances are prescribed at the upper boundary. The conditions of substances interconnection with the underlying surface are given at the low boundary. The parameterizations of the surface and boundary layers are used taking into account the land use categories.

The discrete model approximations and modeling techniques are built with the help of variational principle. To formulate the variational principle and organize the modeling system, some functionals on the set of the state functions should be given.

The models of the processes are written in the variational form by means of the integral identity of the type (4). Such approach provides designing all necessary constructions. The following elements of the model technology are built: algorithms for the main problems, algorithms for adjoint problems, algorithms for calculation of the sensitivity functions, sensitivity relations for given set of
functionals.

As it is provided in the project, the modeling site is the Tomsk region. The problem is solved in the domain of 100 x 100 km in horizontal dimensions with the center coinciding with the city center. The upper boundary is 700 mb surface. The horizontal grid size is 1 km. With the use of ISIREMM data the daily behavior of atmospheric circulation has been simulated. The input meteorological data was taken for 10-11 of February 2001. For the period, the weak (about 5 m/s) background atmospheric flow was observed over the region. The amplitude of the daily surface temperature changes was from 10 to 12 degrees in dependence on the measuring point. The minimum night temperatures were about –25-27C, and maximum day temperature were about –13-15C. It is shown, the wind structure is formed as a result of interconnection between the relatively weak background flow with the city heat island. The temperature contrasts between the particular parts of the underlying surface have a pronounced effect on the results. The character of the movement changes during the day.

SRI

Main attention was paid to investigation of ways to incorporate data retrieved from remote and acoustical sensing to determination of the initial and boundary conditions. Concrete definition of the problem involves setting up the initial and boundary conditions, determining coefficients in equations of the model, specifying source terms, etc. This process is the most difficult stage of model construction. The boundary conditions are being set with regard to special features of the locality wherein the pollutant spreads. The upper boundary of the computational domain the impermeability condition is formulated at the bottom of the inversion layer, which height is determined by means of acoustic sounding. The lower boundary of the domain is at a level of the roughness length $z_0$ and land use categories. The both are retrieved from satellite images of the area under consideration. Performed consideration allows one to deals with 2-D problem instead of troublesome solution of 3-D problem equations.

BISIP

Mathematical simulation of pollutant propagation near emissive sources was performed within the scope of this work package. In particular, Mathematical model of impurity propagation from transient sources was developed within the the Monin – Obukhov’s theory frameworks for profiles of wind velocity and turbulent diffusion coefficient in the near-ground atmospheric layer. Also the Lagrangian approach is used for mathematical simulation of impurity propagation from pulsed sources in dependence on near-ground atmospheric layer stratification (neutral, unstable or stable).

WP 10: Documentation and dissemination

IAO

Within this WP the Russian language project web server was launched, materials describing the project were prepared and disseminated to targeted audience at appropriate meetings, conferences and during visits to different scientific centers both in the NIS and the EU. Special Session devoted to the project start was organized on ENVIROMIS 2000 Conference (Tomsk, 2000), a booklet describing the project was printed and distributed among its participants. Information on the project was included into CD with the Conference Proceedings.

ICMMG

Dissemination activity was performed via active participation in number of international Conferences publicizing the project first results.

SRI

The team input into this kind of activity was done by means of presentation of results achieved at Conferences and participation in project meetings.
BISIP

The team participated in preparation of documentation required and in publicizing the project results.

NRD

Here NRD group members using their position within the Tomsk Regional Administration publicized the project, its first results and potential benefits for regional managing bodies and population at regional and national level. Several papers were also delivered at National and international Conferences. Head of the Group Prof. R. Tukhvatulin participated in organization and run of ENVIROMIS 2000 Conference where special Session devoted to the ISIREMM project took place.

Publications and Papers

ESS


IAO


ICMMG


(tavailable also as DMI Scientific Report, No. 01-04, 2001)


Penenko V.V., Tsvetova E.A. Numerical models and methods for revealing the risk and vulnerability domaines. Computational technologies, 2002 (in press)

Korotkov M.G. Numerical modeling of the daily behavior of the atmospheric circulation in the Tomsk region Computational technologies, 2002 (in press)

Papers


Tsvetova E.A., Penenko V.V. Adjoint equation and splitting technique for fast data assimilation and sensitivity studies. The 33rd International Liege Colloquium “The use of data assimilation in coupled hydrodynamics, ecological and bio-geo-chemical models of the ocean”.

MODAS 2001, Irkutsk

Penenko V. Monitoring, diagnosis and forecast of pollutant transport

Penenko V., Tsvetova E. Mathematical models for revealing the domains of increased ecological risk/vulnerability

Tsvetova E., Penenko V. Fast data assimilation in atmospheric and oceanic studies.

Boyarshinova E. Investigation of the algorithms for numerical solution of mezo-meteorological problems of atmospheric dynamics over complex relief.

Kurbatskaya L. The model of city heat island in the stable background atmosphere

Pozdnyakova N. Design of numerical model of photochemical oxidation in the atmosphere of industrial regions.
SRI
Zakarin E. Urban air pollution modeling in GIS. Int. Conf. ENVIROMIS 2000. Tomsk, Russia, October, 24-28, pp. 36-37

BISIP

NRD
Outline Plans for the next year

ESS
The second year of activities will be dedicated to the second and third Milestones, End of the initial implementation phase and the Component development phase with its implications for further systems integration.
In addition, dissemination activities will proceed as planned.

IAO

WP 00: Project administration
To continue assistance in coordination of NIS part efforts.

WP01: Description of the work
To assist P08 in completing the work and preparing of relevant deliverables.
With assistance of P01 and other partners to customise the software system for the use with the Regional and City Administration of Tomsk and prepare relevant deliverables.

WP 03: Remote sensor development
To accomplish finally modernisation of the set of stationary remote sensors intended for environmental monitoring of the atmosphere over Tomsk City and to construct mobile units equipped with remote and local sensors of meteorological quantities as a means of collecting supplementary data in support of stationary monitoring.
To prepare relevant deliverables.

WP 04: Baseline simulations
To assist partners, mainly P04, in performing a set of baseline simulations as reference case for future industrial pollution related scenarios and model applications and in integration with system platform and application, including preparation of appropriate interfaces, implementation in system prototypes and testing, field trial of integrated air quality system, and the assessment (long term and short term) of air quality management targets.

WP 05: Monitoring data integration
To extend the set of simulation models of the original ECOSIM/AirWare system to directly utilise volumetric and planimetric data obtained from acoustical, optical remote sensors (sodars and lidars) and to develop data assimilation methods for effective use of lidar and sodar data in prognostic 3D models of air quality.

WP 06: Client-Server Communication
To assist P07 in development, implementation and testing a communications system based on a distributed client-server architecture, aiming specifically at low-bandwidth clients such as standard PCs running browser software such as Netscape or the MS Internet Explorer and to organise online connection with the mobile and stationary sensor-stations.

WP 07: 3D model development
To assist P03 in coupling 3D models for city and regional scale pollutant transport to monitor environmental impacts of an industrial center on neighbouring regions and to determine the interrelations of air quality in the system "city-region".

WP 08: System implementation and testing
With principal assistance of P01 and P08 to implement the integrated system for the test case of the city of Tomsk to start its test and evaluation in course of practical applications.
WP 09: System evaluation
With principal assistance of P01 and P08 to start the ISIREMM system evaluation against the user requirements and to start evaluation of its operational use in the city.

WP 10: Documentation and dissemination
To continue effort in assistance to P01 in preparation of the systems documentation, and in dissemination of material describing the project.

ICMMG

WP05
In collaboration with P02, P05 and P06, to describe algorithmically the operators of the models of observations (2) for data assimilation in the fast mode.

WP07
- to couple 3D models for city and regional scales pollutant transport
- to design algorithms of the direct and inverse modeling approaches on the base of the 3D transport models
- to solve the problems of source-receptor and receptor-source types for the modeling site
- to prepare Deliverables D07.1, D07.2

WP10
- 25th NATO/CCMS International technical meeting on air pollution modeling and its application. 15-19 October, 2001, Louvain-la-Neuve, Belgium (Penenko V.)
- MODAS-2, 2002 (5-7 persons)

AUT
AUTH/LHTEE plans to finalize (with the aid of collaborating partners) the selection of the scenarios to be studied, and to perform the simulations.

More specifically, AUTH/LHTEE will complete the study of the meteorological and emission scenario parameters, and will select a number of related scenarios that represent in an optimum way the air quality problem of the Tomsk Greater Area. As the latter is located in an industrial Siberian region, the main focus will be on industrial and central heating related emission scenarios. Modifications might be required regarding the treatment of some of the physical parameters in the air quality modelling, due to extreme weather conditions. It should be noted that there are very few AQ simulation studies available for regions such as the one studied in ISIREMM.

After the selection of the scenarios, AUT/LHTEE will compile the simulations and modify results so that can be fitted in the ISIREMM system.

A number of scientific publications is also among the goals for the next reporting period.

SRI
- Development of the structure of information system of urban air pollution modeling on the base of GIS and client-server technology.
- Modification of the mathematical model accounting for wind vertical profile and ground surface absorption.
- Analysis of acoustic sensing data with the aim to formulate the function of wind vertical distribution and inversion layer dynamics.
• Input / analysis of the land-use map with the aim to estimate dry deposition velocity distribution.

BISIP

WP05

• **Refining the procedure to lidar monitor pollutants of air basin over an industrial center.** There will be refined a lidar procedure to routinely monitor air pollution over an industrial center. The objective is to obtain general characteristics of spatial pollutant distributions of the air basin over an industrial center and to expose regions with higher pollution levels on the base of the analysis of routine field lidar measurements. The procedure of lidar monitoring and algorithms for data processing will be oriented towards gathering information to construct models of pollutant transport.

• **Validating the simulation results on pollutant transport from a pulse source.** There will be designed a procedure to compare lidar data with mathematical simulations of pollutant transport from a pulse source. The comprehensive investigations of spatial distribution of a suddenly-arising mixture cloud will be compared with computation results by using lidar and other sensors.

WP06

Design of lidar database.

There will be designed software to construct a lidar database. It should provide the archiving, ordering, and processing of source and roughly-processed lidar data files to transfer the lidar information to the ISIREMM database. The database will be structured by processing levels of lidar files starting from source files with digitised lidar signals and service parameters up to object levels with graphic and other information on spatial and temporal fields of atmospheric polluting components.

The adaptation of the database to the requirements of the ISIREMM system should be continued at stage 3b within the scope of tasks WP08 and WP09.

WP07

Elaboration of requirements to lidar data for their application in 3D models.

There will be elaborated requirements to the scales of spatial and temporal averaging of pollutant fields with using the lidar data to determine boundary conditions while simulating pollutant transport and testing the models.

SILOGIC

WP01

Consolidation of user requirements with the end-user partners shall be achieved. These requirements may be revised and refined according to feedback and test results on the prototyping done in WP6.

WP06

Technical specifications and software requirements will be completed. First prototypes of communication software components will be developed and will be deployed on the system. Provisioning of network and tools resources and of associated documentation will be checked and finalised in order to be ready to start system’s integration and testing.

NRD

WP00

In collaboration with partners NRD will assist Coordinator in coordination of the project activities.
WP01
During the second year updating of current data collections is planned. Special efforts are planned to be devoted to more detail description of polluting role of the transport, including diurnal and seasonal variations as well as to more precise description of city population distribution, including its day-time and night-time variations.

WP04
Efforts will be devoted to development of strategies/scenarios of city air quality improvement and their assessment on the base of historical and current data.

WP05
Participation in assessment of regional base-line meteorological scenarios and determination of environmentally “worst” cases is planned.

WP06
In collaboration with P02 online connection with the state owned sensor meteorological and air quality monitoring stations NRD group will be organized.

WP08
Regional assistance to relevant stages of system implementation and testing will be organized.

WP09
Participation in development of system test criteria is planned.

WP10
In collaboration with partners continue efforts aimed at dissemination of information on current project results and its potential usefulness anticipated.
MANAGEMENT REPORT

Organisation of the collaboration

The overall project management is based on regular meetings and communication of two bodies, namely

- The Project Steering Committee (PSC) with a representative from each partner and end user representatives, chaired by ESS.
- The Project Technical Steering Committee (TSC), again with at least one representative from each project partner; a rotating chairmanship, reflecting shifting responsibilities during the project, with IAO providing the initial chairman
- Additional meetings and staff exchange of varying groups of partners took place (see below) to ensure co-ordinated development of the parallel, but interdependent Work Packages.

Communications between the partners during the development and test phase rely heavily on electronic media (e-mail, ftp, WWW) to ensure a fast and efficient exchange of comments, documents and data and code. However, collaboration for the individual case studies also relies on site visits and face-to-face discussions, in particular with the end users, in addition to any electronic communication.

In addition to the e-mail through the project mailing list ESS has set up a dedicated ftp server (also accessible through the project home page on the web) as a common and generally accessible repository for relevant project documents, documentation, and data format and interface examples. Also the project WWW server and home page are maintained by ESS (http://www.ess.co.at/ISIREMM). This allows direct access to the latest versions of all project documents including the individual case studies and related multi-media documents, with multiple indexing, full text search, and easy-to-use hypermedia structures.

Several mirrors (most notably at IAO) of the ftp and WWW server have been set up at the NIS partner institutions.

Meetings

First NIS Consortium Meeting

date: 24 October 2000,

place: Tomsk, Institute of Atmospheric Optics premises.

purpose: Discussion of NIS participants related part of the Project and the ISIREMM Project presentation to participants of ENVIROMIS 2000 international Conference “Environmental Observations, Modeling and Information Systems as tools for urban/regional pollution rehabilitation” and to the targeted audience from city and region administration.

Participants: IAO team members (Dr. Balin Y.S., Dr. Bogushevich A.Y., Dr. Fazliev A.Z., Golovko V.F., Prof. Gordov E.P., Dr. Krutikov V.A., Prof. Polichtchouk Yu. M., Prof. Starchenko A.V.);

ICMMG team members (Dr. Bushenkov Yu.M., Dr. Korotkov M.G., Prof. Penenko V.V., Dr. Tsvetova E.A., Dr. Yudin M.S.);

SRI team members (Mr. Akhmedzhanov A.K, Mrs. Dedova T.V., Dr. Kazmirchuk L.A., Mr. Sakhariev B.S.),

BISIP team members (Dr. Barun V.V., Dr. Chaikovskii A.P., Prof. Kabashnikov V.P.),
NRD team members (Dr. Adam A. Tomsk regional ecological Committee, Mr. Krivoshapko A.I., Tomsk Regional Hydrometeorology Committee, Prof. Tuhvatulin R.T., Mr. Zinenko V.N., West-Siberian Department of Russian Hydrometeorology Service, Novosibirsk).

Results: Data formats, requirements and means of data exchange were discussed. Direct cooperation between researchers from partner organization was established.

Project Kick-off Meeting

Date: 11 and 12 December 2000

Place: ESS offices, Gumpoldskirchen, Austria

Participants:

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<th>ESS</th>
<th>Kurt Fedra</th>
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<td>Lothar Winkelbauer</td>
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<td>ICMMG</td>
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<td>SILOGIC</td>
<td>Benoit Baurens</td>
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<td>NRD</td>
<td>Ravil’ Tuhvatulin</td>
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The kick-off meeting did serve several important objectives:

- Establish a direct **personal relationship** between participants in a first face-to-face meeting, especially important for those that have not yet met and worked together;
- Establish the various committees and the **organisational and communication structures** for the project;
- Clarify project administrative matters such as **reports and cost statements**;
- Clarify technical details such as **data formats** for communication;
- Discuss the details of the **work plan implementation**, with emphasis on the first 12 months and the first set of Deliverables;
- Fix a list of **ACTION ITEMS** for the detailed work plan for the coming months.

Second NIS Consortium Meeting

Date: 25-26 June 2001

Place: Irkutsk, Limnology Institute premises

Purpose: Discussion of current state of the art and problems appeared in performance of NIS participants related part of the Project and the ISIREMM Project presentation to participants of MODAS 2001 “International Conference on Modeling, Databases and Information Systems for Atmospheric Sciences”.

Participants: IAO team members (Mr. Babikov Yu.L., Dr. Balin Y.S., Dr. Bogushevich A.Y., Dr. Fazliev A.Z., Golovko V.F., Prof. Gordov E.P., Dr. Krutikov V.A., Prof. Polichtchouk Yu. M.);

ICMMG team members (Mrs. Boyarshinova E.A., Prof. Penenko V.V., Ms. Pozdnyakova N.S., Ms. Zinovieva I.V.);

SRI team members (Dr. Ismailova B.B., Dr. Kazdayev N.Kh., Pankratov V., Prof. Zakarin E.A.)
**BISIP team members** (Dr. Chaikovskaya L.I., Dr. Chaikovskii A.P., Academician Ivanov A.P., Prof. Kabashnikov V.P.),

**NRD team members** (Mr. Kolotovkin I.V., West-Siberian Department of Russian Hydrometeorology Service, Novosibirsk).

**Results:** Mainly mutual data requirements and means of data exchange were discussed. A way to pass data from Kazakhstan to Tomsk and backward was elaborated. Particular measures to accelerate partner inputs to task performance were discussed and elaborated. Direct cooperation between researchers from partner organization was improved.

**Outline of meetings planned for the next year**

The next technical and management meeting will be held in Gumpoldskirchen in November 2001.

A project meeting in Tomsk is suggested on July 4-6, 2002 to discuss first results of ISIREMM Demonstrator test runs and to take them into account in course of subsequent project performing.

**Exchanges**

None

**Problems**

Encountered problems are mainly financial however they cause management and administrative problems as well. The first problem is caused by discrepancy of national regulation of currency, which require to convert (sell) ½ of coming currency into RUR immediately and EC rule for calculation of expenses in EURO on the base of monthly exchange rate.

The second problem is caused by fact that EC does not justify VAT while in spite of Agreement between RF and EC on 16 October 2000 on special taxation of EC funded project any item bought is subjected to VAT in Russia. Both problems lead to necessity to cover difference between justified payments and really done from other sources, which cause some management and administrative problems.
INDIVIDUAL PARTNER ANNUAL REPORTS


Primary activities of ESS as project coordinator included

1. The project administration and management
2. The preparation of the ISIREMM Demonstrator and the associated data processing.

Project administration

Main activities included:

1. Organisation of the project kick-off meeting, December 11-12 2000, at ESS premises in Gumpoldskirchen Austria;
2. Implementation of the project communication infrastructure including a mailing list isiremm@ess.co.at, ftp server ftp.ess.co.at, and the project web server http://www.ess.co.at/ISIREMM:

![ISIREMM: Integrated System for Intelligent Regional Environmental Monitoring & Management](image)
The ISIREMM Demonstrator

The demonstration prototype is the basis for the integration of the ISIREMM specific developments, both in terms of models, new data sets, and the web based components of a distributed environmental information system.

The ISIREMM demonstrator prototype is based on the AirWare/ECOSIM air quality assessment and management information system, http://www.ess.co.at/AIRWARE, implemented with the specific data for the City of Tomsk, Siberia.

AirWare is an integrated, model-based information and decision support system for air quality assessment and management. It supports the implementation of European and national environmental legislation such as the European Air Quality Framework Directive 96/62/EC, COM(97)500, or 90/313/EEC on public access to environmental information.

Designed for urban agglomerations and industrial areas, the flexibility of the modular software components makes it easy to adapt and apply the system to a broad range of physiographic and meteorological, socio-economic, and environmental conditions. A client-server implementation exploits the latest network computing technologies.
The ISIREMM Demonstrator combines:

- Integrated data base management for emission inventories and meteorological and air quality data; storage of the time series data in a relational data base makes the linkage of the data base server to on-line monitoring systems straight forward;

- A suite of simulation and optimisation models for strategic analysis, optimisation, and operational forecasting, including a generic interface to external models to be developed within the ISIREMM framework, together with

- A geographic information system covering three domains from the city scale to a larger part of Siberia, providing background data for the interpretation of the simulation results, and spatial inputs such as DEM, land use, road network, and population data, and

- Embedded expert systems functionality assisting user interaction and in particular parameter estimation, especially emission data, and

- Assessment and reporting functions, primarily population exposure analysis.
The ISIREMM demonstrator implements the basic data sets (described in Deliverable D01.2, Data Availability Report) in an application for the City of Tomsk and the surrounding region. The Demonstrator also features a generic interface to external models, preparing the integration of specific developments foreseen for the second project year.

The ISIREMM prototype 0.1 is based on AirWare release 4.8.

Reference and User Manuals for AirWare are available under
http://www.ess.co.at/EUREKA/MANUALS/manual.html, accessible through the ISIREMM project web pages (http://www.ess.co.at/ISIREMM).

The embedded help- and explain system uses HTML format with a browser derived from Mosaic.

The system is implemented under Linux (Red hat 7.1), an open-source operating system.

The system can run on any PC with an Intel (or compatible) processor that supports Linux. A screen resolution of 1280*1024 pixels with 24 or 32 bits color resolution (true color) is required.

The AirWare software is written in C/C++ using the public domain X11/Xlib graphics library for all graphical interface functions.

The implementation uses MySQL as its relational data base engine. MySQL is available with the standard Linux distribution under the GNU licensing policy.

The implementation requires approximately 110 MB of disk space with a one year (2000) data set of meteorology and air quality observations.

The system will be implemented on an appropriate workstation in Tomsk, and a mirror implementation will be available at ESS in Austria. Upgrades will be performed through ftp.
ANNUAL REPORT

Institute of Atmospheric Optics of Siberian Branch of Russian Academy of Sciences (P02)

Contract Number: ICA2-CT-2000-10024

Integrated System for Intelligent Regional Environmental Monitoring & Management

01 October, 2000 – 31 September, 2001

Introduction

The main objectives of the scientific group of the Institute of Atmospheric Optics SB RAS (P02) during the first year of the Project are to lead work aimed at software adaptation and implementation, remote sensor development and monitoring data integration and to participate in work devoted to Project administration within NIS partners, Baseline simulations, Client-Server Communication, 3D model development and Documentation and dissemination.

According to the Working Plan, group P02 performed these studies within the frame of tasks WP00 – WP07, WP10 during the first executive year.

Description of work

Within the WP 00: Project administration the IAO team assisted to the Coordinator in coordinating the project activity of NIS Consortium Partners, firstly to this end the Russian language project Internet site was developed and opened (http://isiremm.iao.ru/russ/ISIREMM/ISIREMM.php). Special NIS partner’s management meeting was organized during the MODAS Conference in Irkutsk, 25-29 June 2001. Communications within NIS partners and assistance to the Coordinator in such communications had been organized, especially during preparation of progress reports, the preparation of review meetings, and compilation of cost statements.

Within the WP 01: Requirements analysis and data compilation the group performed jointly with P08 compilation of user requirements and constraints, analysis of data requirements and data availability, compilation of the basic data sets for the initial implementation and testing of the software system. Jointly with the Coordinator (P 01) and with assistance of other Partners, mainly P08, a consistent set of background data for the indicator development, the scenario analysis and model applications was chosen and prepared. All these data were organised into shared data structures in electronic form (text files, spreadsheets, data bases, and GIS data) and http and ftp access to the project information resources was provided for the Partners. Special attention was paid to preparation of additional layers for GIS of the Tomsk city and neighbouring regions. For example DEM were developed for the selected domains, which are the city suburbs (100km*100 km) and South of West Siberia (1400km*1400km), in the standard required by the MEMO model employed by P05. The surface model is given as a rectangular grid built in Lambert Equal-Area Azimuthal projection. Altitudes of grin nodes are calculated on the base of digital map horizontals by the Kriging method.

This results are presented as three files with following characteristics.
Within the **WP 02: Software adaptation and implementation** IAO team efforts were concentrated mainly on pre-processing the data compiled in WP 01 for the system and on developing GIS-applications and meteorological databases of the city and region based on WP 01 results. It includes development of GIS-applications and meteorological databases of the city and region based on WP 01, compilation of applicable national and regional legislation and organization of online connection with the mobile and stationary sensor stations. Relevant databases are prepared. Software supporting online connection is developed and tested for the TOR-station, which is an IAO set of stationary sensors and relevant site is open in Internet (http://meteo.iao.ru/?lang=eng). An example of data presentation is shown on Fig. 1.

![Fig.1.](image_url)

Within the **WP 03: Remote sensor development** IAO activity was devoted to modernisation of the set of stationary remote sensors (lidars and photometers) intended for environmental monitoring of
the atmosphere over Tomsk City, to design and construction of mobile units equipped with remote and local sensors of meteorological quantities as a means of collecting supplementary data in support of stationary monitoring and to development of the software tools for real-time data acquisition, processing, and preliminary analysis.

The aerosol lidar LOZA–M is scanning system to be used for environmental monitoring of the atmosphere over Tomsk City. It has been modernized compared to that previously used to improve positioning characteristics. Both lidar recording and control system which was developed are now based on an PC. A device of digital recording of lidar returns was set in the standard of this computer and was built directly in a processor.

Basic design specification of the LOZA-M lidar are: operation range 5-7 km, wavelength 0.53 mkm, spatial resolution 7.5 m, angular resolution 10 min of arc and mass 70 kg. The lidar accomplishes two modes of operation. The first one is accomplished in the manual scanning regime in which displacement of a sounded object cannot be predicted and must be followed using visual observation. An operator turns the column at the prescribed angular velocity within the preset sectors of horizontal and vertical scanning. In this case for each laser shot the information about the direction of sounding and the digitized values of lidar returns from the examined atmospheric objects are entered into the computer memory from the sensors of the elevation angles. The second type of operation is completely automated measurement controlled by a special program. It incorporates two basic regimes: position and sector scans. In the position regime under instructions (Azimuth, Angle of elevation, and Angular velocity) keyed in by the operator, the optical axis of the lidar transceiver is set on the given point and is hold in this position during sounding. This regime is used in sounding of plumes from local pollution sources to measure the strength of their emissions. The lidar transmitter block is shown on Fig. 2.

Each sounding step is organized into an individual data file. A serial number is assigned to this file which comprises a shot data sheet with measurement time and other specifications. During the experiments in synchronism with the lidar measurements, the visual information was recorded on a video with the TV–camera. Thus some supplementary data were obtained for subsequent interpretation of the results of sounding.

Modernized Raman lidar is based on the air borne lidar M2M, which proved its reliability in plenty of field works and is aimed at remote determination of SO2 concentration in gas mixture leaving industrial stacks. Optico-mechanical block is not changed, which allowed us to use the same laser, frequency doubler and telescopes. Registration block is subjected to modernization and now is adjusted to spectral separation of the signals required for SO2 concentration measurements. Modernized Raman lidar should allow one to arrive to 75 mln\(^{-1}\) minimal detectable SO2.
concentration at 15 minutes measuring time.

Modernized panoramic (all-sky) photometer aimed to monitoring industrial plumes and cloud patterns consists of an opto-electronic modulus placed on the roof of the IAO building (see Fig.3) and remote registration and pre-processing block.

![Fig.3](image)

The opto-electronic block employ two video cameras Digital8 Sony TRV730 to get images either all sky hemisphere or its chosen parts. The registration and pre-processing block allows to get panoramic images $576 \times 576$ pixels and localized images $768 \times 576$ pixels. Registration can be done in the continuous regime (25 frames/sec) or in the single frame regime (0.2 sec per frame). Results of current sky observations are presented in Internet (http://nebo.iao.ru/).

Mobile station “Atmosphere-K2” equipped with remote and local sensors of meteorological and air quality quantities as a means of collecting supplementary data in support of stationary monitoring is designed and developed. It includes an meteorological system with a meteorological mast, an aerosol complex, a gas analysing complex, a registration system, provided with ADC and radio modem. The station allows one to measure the following characteristics: aerosols disperse content, aerosol scattering and absorption coefficients, pressure, temperature, humidity, wind velocity and direction, solar radiation, ozone, NO, NO$_2$ and SO$_2$ concentrations.

Software supporting real time communications with the system server is currently in process of design.

Within the WP 04: Baseline simulations investigations of air quality related to the meteorological and land use features of the city of Tomsk are performed, a set of meteorological scenarios leading to bad environmental situations were determined from historical data thus giving the background for modelling applications. In particular, air quality data from WP01 were investigated with relation to the meteorological and land use features of the Tomsk city, which lead to a set of representative meteorological scenarios for the area. An example of synoptic description of weather in Tomsk for the chosen for air quality modelling dates in 2000-year looks like following.

10 – 11 January

During near all 10-th January weather was determined by the contrast zone, which appears at the periphery of the multi-central Atlantic cyclone and Asia anticyclone. Till 7 AM the weather in the city was formed by the upper warm front. Meanwhile the cyclone was moving long the North of the Eurasia and after 9 PM the weather was formed by its south eastern part. Its influence took place during 11-th January as well. However at 4 AM the warm Arctic front went above the city and the continental Arctic air mass was changed to the moderate one.
Currently the modelling of scenarios for the chosen dates is performed.

Within the **WP 05: Monitoring data integration** activity was focused adaptation of the set of simulation models of the original ECOSIM/AirWare system to direct usage utilise volumetric and planimetric data obtained from optical remote sensors (lidars) and from satellite imagery, relevant data assimilation methods for effective use of such measurements were developed and tested during special campaign.

![Fig. 4](image)

The first step of activity comprise the development of modelling software to directly utilise data from the remote sensing instruments performing 3D atmospheric parameter measurements with on the basis of WP 04 and the parallel WP 07 intermediate results, an optimal regime of remote sensor operation (frequency of measurements, averaging period, etc.). A simplified model for air quality prediction on the base of the remote sensor data is suggested, in which non-stationary one-dimensional boundary layer model is employed for wind and turbulence dynamic characteristics determination. In the simplified model current meteorological data (temperature, humidity and turbulence) are used as boundary conditions, which allows one to get operative data for city atmosphere pollution. It is shown that such approach can not be used for surfaces with non homogeneous surface temperature and orography. To test the model forecasted wind and turbulence data were used for numerical prognoses of Tomsk power station GRES-2 plums transport above the city. The Lagrange trajectory stochastic model was used for numerical simulations. Lidar measurements of the plum were performed during 23 April –11 May 2001 to verify model predictions. The LOZA-M lidar scanned 22 degree sector with the GRES-2 stack in it, the distance to the stack is 3 km. It provides 3-D industrial aerosol backscattering coefficient distributions, which were used for the model validation. An example of experimental data is shown on Fig.4. Here $\alpha(z)$ ([$\text{km}^{-1}$]) is aerosol backscattering coefficient going along $Z$, $X$ and $Y$ show distance to the plum sounded, the scale for $\alpha(z)$ magnitude from the right hand side shows its
growing with darkening. Additional information is fixed on the picture as well, which is the line of sight elevation angle, maximal $\alpha(z)$ magnitude in current scanning, date and time of the current measuring cycle start.

Data retrieved from the experimental campaign were compared with relevant numerical prognoses. Fig. 5 shows comparison of those for 24 April 2001.

![Fig. 5.](image)

Here the stack is placed at (0,0) point, both numerical (colour domains) and experimental (contour lines) data are averaged for 500meter near-surface layer. One can see quite good agreement of numerical prognoses with real 3-D behaviour of the plum.

The second simple model developed is aimed at determination and prognoses of hazardous UV B radiation ($280<\lambda<315$ nm) at selected area (city and its nearest suburbs used as recreation place) on the base of its local measurements. Aerosol and cloud distribution in atmosphere determining amount of UV radiation reaching the surface is planned to be retrieved from aerosol lidar and all sky photometer measurements. Algorithms based on the Monte-Carlo method are time consuming and bulky. The suggested simplified approach is based on the Eddington method. Performed study shows that this approach can be used both for cloudiness and cloudless atmosphere. Fig. 6 shows comparison of numerical simulations performed on the base of the Monte-Carlo method and the simplified model.
Here shown is diffuse transmission of atmosphere for clear sky by Eddington with effective optical depth, albedo and zenith angle for clouds type C. Cloud depth are 0.2, 1, 2 km, solar zenith angle 40.

Within **WP 06: Client-Server Communication** software supporting online connection of stationary sensor-stations with a server was developed and tested. As an example the IAO Aerosol station Internet site (http://aerosol1.iao.ru/index.e?lang=eng) is shown on the Fig.7. Here results of regular measurements of atmosphere aerosol characteristics as well as relevant meteorological characteristics performed at the Aerosol station are presented in real time regime. All software designed is based on the Internet technologies. Similar work was performed at the IAO TOR station. The software developed and tested will be used to support data transmission from the mobile sensor unit as well.
Within the **WP 07: 3D model development** main efforts were devoted to coupling 3D models for city and regional scale pollutant transport to monitor environmental impacts of an industrial center on neighbouring regions. To describe dynamical and thermal processes above the city the following mathematical model was used.

\[ \frac{\partial \rho W_i}{\partial x_i} = 0, \]

\[ \frac{\partial \rho W_j}{\partial t} + \frac{\partial \rho W_j W_j}{\partial x_i} = -\frac{\partial P}{\partial x_j} + F_j + K_H \left( \frac{\partial^2 W_j}{\partial x_1^2} + \frac{\partial^2 W_j}{\partial x_2^2} \right) + \frac{\partial}{\partial x_3} \left( K_Z^m \frac{\partial W_j}{\partial x_3} \right), \]

\[ \frac{\partial \rho \Theta}{\partial t} + \frac{\partial \rho \Theta W_j}{\partial x_i} = K_H \left( \frac{\partial^2 \Theta}{\partial x_1^2} + \frac{\partial^2 \Theta}{\partial x_2^2} \right) + \frac{\partial}{\partial x_3} \left( K_Z^h \frac{\partial \Theta}{\partial x_3} \right), \]

\[ \frac{\partial \rho q}{\partial t} + \frac{\partial \rho W_j q}{\partial x_i} = K_H \left( \frac{\partial^2 q}{\partial x_1^2} + \frac{\partial^2 q}{\partial x_2^2} \right) + \frac{\partial}{\partial x_3} \left( K_Z^h \frac{\partial q}{\partial x_3} \right), \]
\[ P = \rho R_{air} T, \quad R_{air} = R_0 \left( \frac{1 - q}{M_{air}} + \frac{q}{M_{H2O}} \right). \tag{5} \]

Here \( F_1 = \rho f W_2; \ F_2 = -\rho f W_1; \ F_3 = -\rho g; \ K_H, K_Z^m, K_Z^h \) are turbulent diffusion coefficients, \( f \) is the Coriolis parameter, \( q \) is air humidity, \( R_0 \) is the universal gas constant; 
\[
\Theta = T \left( \frac{P_0}{P} \right)^{R_{air}/c_p}.
\]

The vertical turbulent diffusion coefficients \( K_Z^m, K_Z^h \) are determined on the base of "k-L" turbulence model, while horizontal turbulent diffusion coefficient is assumed to be constant. Boundary conditions were chosen as
\[
\frac{\partial W_1}{\partial x_3} = \frac{\partial W_2}{\partial x_3} = W_3 = \frac{\partial \Theta}{\partial x_3} = \frac{\partial q}{\partial x_3} = 0,
\]
for upper boundary and for the side boundaries “radiation” conditions were used:
\[
\frac{\partial \phi}{\partial t} + C_{\phi} \frac{\partial \phi}{\partial n} = \frac{\partial \phi_M}{\partial t} + C_{\phi} \frac{\partial \phi_M}{\partial n}, \quad \frac{\partial W_3}{\partial x_3} = 0, \quad \phi = W_1, W_2, \Theta, q.
\]

The underlying layer temperature \( \Theta_0 \) is determined from the following prognostic equation:
\[
\frac{\partial \Theta_0}{\partial t} = - \frac{3.72}{\rho_s c_s d} \{ (1 - A) F_s + F_A - F_L - H_0 - E_0 \} - \frac{7.4 (\Theta_0 - T_{soil})}{\tau_d}, \tag{6}
\]
where \( \rho_s, c_s, \lambda_s, T_{soil} \) are known soil characteristics. Solar and long wavelength radiation fluxes were calculated according Albrext and Brent, while turbulent heat fluxes were determined on the base of Monin-Obukhov theory. This non hydrostatic model of lower boundary layer allows one to obtain detail pattern of circulation, thermal and humidity state of the system “atmosphere + underlying surface”. To initialise it adequately the following one dimension non stationary model for atmospheric boundary layer was used:
\[
\frac{\partial W_1}{\partial t} = - \frac{\partial}{\partial x_3} \langle w_1 w_3 \rangle + f \langle W_2 - W_2^{geo} \rangle,
\]
\[
\frac{\partial W_2}{\partial t} = - \frac{\partial}{\partial x_3} \langle w_2 w_3 \rangle - f \langle W_1 - W_1^{geo} \rangle, \quad \frac{\partial \Theta}{\partial t} = - \frac{\partial}{\partial x_3} \langle w_3 \Theta \rangle, \quad \frac{\partial q}{\partial t} = - \frac{\partial}{\partial x_3} \langle w_3 q' \rangle.
\]

Here \( W_1, W_2 \) are the horizontal wind components \( (W_3 \equiv 0) \), \( W_1^{geo}, W_2^{geo} \) are the geostrophic wind components.

The above model was used for simulation of pollutant transport in Tomsk city. The city land use categories and relief are shown on Figs. 8 and 9.
Pollutant transport for 24 April was modelled and results were compared with local and remote measurements performed at the same time. Fig. 9 shows that agreement of simulated and measured characteristics is quite good.
Here black domains are the maximal aerosol concentrations along the laser-sounding path, while blue domains are for the forecasted pollutant distribution.

Within **WP 10: Documentation and dissemination** the Russian language project web server was launched, materials describing the project were prepared and disseminated to targeted audience at appropriate meetings, conferences and during visits to different scientific centers both in the NIS and the EU. Special Session devoted to the project start was organized on ENVIROMIS 2000 Conference (Tomsk, 2000), a booklet describing the project was printed and distributed among its
participants. Information on the project was included into CD with the Conference Proceedings.

**Publications**


Fedra K., Gordov E. Integrated System for Intelligent Regional Environmental Monitoring&


Samoilova S.V., Balin Yu. S. Uase of space borne polarisation lidar for determination of cloud
optical parameters. Izv. RAN, Fizika Atmosfery I okeana, 2001, T.37, №2, pp..201-212


Plan for the next year

WP 00: Project administration
To continue assistance in coordination of NIS part efforts.

WP01:Description of the work
To assist P08 in completing the work and preparing of relevant deliverables.

With assistance of P01 and other partners to customise the software system for the use with the Regional and City Administration of Tomsk and prepare relevant deliverables.

WP 03: Remote sensor development
To accomplish finally modernisation of the set of stationary remote sensors intended for environmental monitoring of the atmosphere over Tomsk City and to construct mobile units equipped with remote and local sensors of meteorological quantities as a means of collecting supplementary data in support of stationary monitoring.

To prepare relevant deliverables.

WP 04: Baseline simulations
To assist partners, mainly P04, in performing a set of baseline simulations as reference case for future industrial pollution related scenarios and model applications and in integration with system platform and application, including preparation of appropriate interfaces, implementation in system prototypes and testing, field trial of integrated air quality system, and the assessment (long term and short term) of air quality management targets.

WP 05: Monitoring data integration
To extend the set of simulation models of the original ECOSIM/AirWare system to directly utilise volumetric and planimetric data obtained from acoustical, optical remote sensors (sodars and lidars) and to develop data assimilation methods for effective use of lidar and sodar data in prognostic 3D models of air quality.
WP 06: Client-Server Communication
To assist P07 in development, implementation and testing a communications system based on a distributed client-server architecture, aiming specifically at low-bandwidth clients such as standard PCs running browser software such as Netscape or the MS Internet Explorer and to organise online connection with the mobile and stationary sensor-stations.

WP 07: 3D model development
To assist P03 in coupling 3D models for city and regional scale pollutant transport to monitor environmental impacts of an industrial center on neighbouring regions and to determine the interrelations of air quality in the system "city-region".

WP 08: System implementation and testing
With principal assistance of P01 and P08 to implement the integrated system for the test case of the city of Tomsk to start its test and evaluation in course of practical applications.

WP 09: System evaluation
With principal assistance of P01 and P08 to start the ISIREMM system evaluation against the user requirements and to start evaluation of its operational use in the city.

WP 10: Documentation and dissemination
To continue effort in assistance to P01 in preparation of the systems documentation, and in dissemination of material describing the project.
ANNUAL REPORT
P03- Institute of Computational mathematics and mathematical geophysics SD RAS

Contract: ICA2-CT-2000-10024

Integrated System for Intelligent Regional Environmental Monitoring & Management
“ISIREMM”

WP00
Administrative activity is aimed at promoting better conditions of the work, coordination of the efforts inside the team and links with the partners

WP01
As applied to the aims of the project, some aspects of interconnections between ISIREMM data base and the models developing by P03 have been examined. In particular, the joining version of digital maps of relief, land-use categories, emission data, etc have been accommodated for our models.

Two options have been designed for meteorological data and initial fields:
1) research one, when data come just from measurement sites and the reconstruction of initial fields has to be done with the help of data assimilation. This case is mostly typical for our conditions when the lack of data is common.
2) regular one, when all necessary data have been already prepared in the points of the model grid domain

WP02
The capabilities of the ECOSIM/AirWare system have been studied to accumulate the experience on designing the systems for ecological forecasts and to be oriented in the frames of the project.

The preparation has been made to adapt our modelling system for work with data and partners in ISIREMM. The LINUX-server-controlled local laboratory net has been organized.

WP03
The principle tasks have been examined: how to fit and assimilate inhomogeneous data into the models in such a way that the shock-effects to be avoid. For the aim of the project the efficient methods of real-time data assimilation are needed. It is necessary to provide an agreement in resolution in the model and data as well.

Starting from this point, the analysis of the state-of-the-art on data assimilation has been made. The comparison studies on estimation of observability domains of measuring sites and informative quality of data have been made with the help of numerical experiments. In accordance with our considerations, if measured data are used together with models for reconstruction of the state functions, then their common informative quality is essentially higher even if the set of observations is comparatively small. As a consequence, the fast data assimilation procedure on the base of variational principle has been designed (see WP05)
A series of numerical experiments has been made with the help of our 3D numerical model of hydrodynamics of meso-regional scale (see WP07). The model has been used in the research mode (see WP01). It means that the initial state has been reconstructed from the limited set of input data. The daily behaviour of atmospheric circulation has been simulated. The main attention has been focused on the convective processes which might be responsible for accumulation of the pollutants in the particular subdomains. The results of the scenarios have been transmitted to the partners P02 to be analysed.

Some aspects of the use of specific remote sensing data from the ISIREMM data base have been considered. These data can be exploit for the reconstruction of the state functions with the help of the methodology of combined use of the models and data in assimilation mode.

The new fast version of data assimilation technique has been developed. It follows our methodology that combines direct and inverse modelling procedures. The idea of the approach is as follows.

So, the goal is to construct an efficient algorithm of joint use of two basic elements of investigation: model and data.

Suppose, there are

1) a mathematical model

\[
\frac{\partial \phi}{\partial t} + G(\phi, \psi) - f - \phi = 0, \quad \phi^0 = \phi_0 + \xi, \quad \psi = \psi_0 + \bar{\psi};
\]

and 2) a set of measured data

\[
\psi_m = [H(\phi_m)]_m + \bar{\psi}_m,
\]

where \( \phi \) is the state function, \( \phi^0 \) is initial data, \( \phi^* \) is the vector of model parameters, \( \psi_0, \psi^0 \) are their \textit{a priori} estimations, \( G(\phi, \psi) \) is a space operator of the model, \( f \) is a source term, \( \bar{\psi}, \bar{\xi}, \bar{\bar{\psi}}, \bar{\bar{\bar{\psi}}} \) are the terms describing uncertainties and errors of the corresponding objects, \( \psi_m \) is a set of measured data, \( H(\phi) \) is a model describing association between the state function and measured quantities.

The problem considered can be solved with the help of variational approach and splitting technique. The generalized quality functional is introduced in the form

\[
\Phi^h(\bar{\phi}) = 0.5 \left\{ \sum_{i=1}^{4} \alpha_i (R_i^T M_i R_i)_{D_i} + \alpha_2 (R_2^T M_2 R_2)_{D_2} + \alpha_3 (R_3^T M_3 R_3)_{D_3} + \alpha_4 (R_4^T M_4 R_4)_{R_4(D_4)} \right\}^{h} + \left[ I^h(\phi, \psi, \phi^*) \right]_{D_i},
\]

where \( M_i, (i = 1, 4) \) are weight matrices, \( \alpha_i \geq 0, \sum_{i=1}^{4} \alpha_i = 1 \) are weight coefficients,

indices \( T, h \) denotes transposition and discrete analogue,

\[
I(\phi, \psi, \phi^*) = \int_{D_i} \left( \frac{\partial \phi}{\partial t} + G(\phi, \psi) - f - \phi \right) \phi \ast dDdt = 0
\]

is the variational form of the model (1), \( \phi^* \) is co-state function, that is generalized Lagrange
multiplier. In this case, the model (1) plays the roles of restriction to the state function and connection between model parameters and the state functions. The inner product in (4) is defined from the energy balance of the system. The first four terms in (3) are the corresponding discrepancy functionals.

A minimization functional problem with respect to the components of the vectors $\rho^0, \phi^0, Y$ is formulated. The set of computational algorithms is obtained from the stationary conditions for $\Phi^h$ to variations of the components of vectors $\rho^0, \phi^0, \phi^0, Y$ on the grid domain $D^h$. As a result of the problem’s solution, functions $\rho^0, Y$ describe the space-time system behaviour, the function $Y^j$ shows the model errors estimated with respect to data $\Psi_m$.

A variational principle is the base for all algorithm constructions. The main inverse modelling procedure that we usually use for data assimilation, leans upon technique of adjoint problems and sensitivity functions generated by (3)-(4). Here we describe the “light” version of assimilation algorithm.

**Fast data assimilation**

To this goal a variational principle for (3),(4) and splitting technique are used. As we concentrate on current data assimilation, let us ignore the initial data and parameter errors in (3). The splitting method as a method of weak approximation with fractional steps in time is applied. It is supposed, that data of measurements and errors of the model are taking into account at the final stage of splitting scheme at each time step.

In this conditions the discrete analogue (3) has the form

\[
\Phi^h(\rho) = 0.5 \left\{ \sum_{j=1}^{jk} \left( \alpha_j (\bar{P}^T M \bar{P})_D + (1 - \alpha_j)(\bar{P}^T M_z \bar{P})_D \right) \Delta t \right\} + I_n^h(\rho, \bar{Y}, \bar{\phi}^*),
\]

\[
I_n^h(\rho, \bar{Y}, \bar{\phi}^*) = \sum_{j=1}^{jk} \sum_{k=1}^n \left\{ \left( \rho^{i-k-n} - \rho^{j-k-n-1} \right) + \Delta t \left[ A_k \left( \rho^{i-k-n} - (\bar{Y} + \bar{P}^e) \delta_{j,j}^{i-k-n} \right) \right] \right\} = 0
\]

where $j$ is the number of time step, $jk$ is amount of time steps, $k$ is the number of the splitting stage, $A_k$ is implicit linearised approximation of split part $G_k(\rho, \bar{Y})$ of the model operator $G(\bar{\phi}, \bar{Y}) = \sum_{k=1}^n G_k(\rho, \bar{Y})$, $n$ is amount of splitting stages, $\delta_{\alpha,\beta}$ is Kronecker-delta. The inner products in (5), (6) are taken over space domains. Formula (6) is approximation of integral identity (4) for the model (1) in terms of splitting technique. As the third term in (5) is equal to zero, the fast assimilation algorithm can be derived from minimum condition for (5) with respect to the components of the state functions $\rho^0$ in the node points of the grid domain $D^h$. Omitting intermediate considerations, let us write the system of equations for calculation of the state functions $\rho^0$ with the use of observed data $\Psi_m.$
\[ \alpha_1 (E + \Delta t A_n)^T M_2 \left( \left( E + \Delta t A_n \right) \overline{\omega} - \Delta t \overline{f} \right) \]
\[ + (1 - \alpha_1) \Delta t H^T M_1 \left( (H \Phi)^j - \overline{\Phi}_m^j \right) = 0 \] (7)

As the starting point of our considerations is (4), we have a possibility to design (5),(6) in such a way that all operators in the splitting schemes are realized with the help of simple and effective direct (non-iterative) numerical algorithms.

Hence, the system of equations (7) is solved by means of direct procedure. The observed data are involved in modelling process as soon as new information becomes available. The algorithm of the solution of (7) is slightly modified one as compared with the realization of corresponding splitting stage without assimilation. Parameter \( \alpha_1 \) is used for control the assimilation procedure. If \( \alpha_1 = 1 \), the model ignores measured data, and if \( \alpha_1 \to 0 \), the data are predominate in calculation of the state functions. Contribution of each element is defined in dependence on the degree of reliance in this component.

The algorithm for fast data assimilation is based on local optimum conditions for objective functionals in the framework of splitting technique that is used for the discrete form of the model. It is realized with the help of a direct modelling procedure that successively assimilates incoming data. The data are included by means of a quality functional at suitable splitting stages and corresponding time steps. The algorithm provides fast data assimilation and reconstruction of state functions with reasonable accuracy. It is more effective in a computational sense. Being combined with the main inverse modelling procedure derived from (3), it generates a good first guess for the solution of inverse problems.

To include the specific remote sensing data into the models of hydrodynamics, transport and transformation of pollutants with the help of the presented technique, it is necessary to describe algorithmically the operators of the models of observations (2). To this goal, the further collaboration with the partners P02, P05, P06 is planned.

WP06

The laboratory server is organized for communication in the client-server mode. The server uses OS Linux.

WP07

The development of the new versions of 3D numerical model of hydrodynamics and pollutant transport are in progress.

Two types of models are designed

1. local-to-regional scales
2. regional-to-global scales

The first type is focused on the study of the quality of the atmosphere in the city (Tomsk) and surroundings (WP04). The large scale models of the second type are necessary to study the scales of interaction in the climatic system, when the Tomsk region plays the role as the source as the receptor of disturbances. They also useful for estimation of the trans-boundary interconnection with the other regions and for evaluation of the risk/vulnerability domains. To this goals, the methodology is organized that is based on the direct and inverse modelling procedures, and sensitivity theory.

The models are written in the surface-following coordinates. The model of the first kind use the Cartesian coordinates on limited area. The geographical coordinates are introduced in horizontal direction in the models of the second type. A hybrid coordinate is used in the vertical that implies the decomposition of the domain into two parts. The models are closed with boundary conditions.
The fluxes of substances are prescribed at the upper boundary. The conditions of substances interconnection with the underlying surface are given at the low boundary. The parameterisations of the surface and boundary layers are used taking into account the land use categories.

The discrete model approximations and modelling techniques are built with the help of variational principle. To formulate the variational principle and organize the modelling system, some functionals on the set of the state functions should be given. The models of the processes are written in the variational form by means of the integral identity of the type (4). Such approach provides designing all necessary constructions. The following elements of the model technology are built:

- algorithms for the main problems,
- algorithms for adjoint problems,
- algorithms for calculation of the sensitivity functions,
- sensitivity relations for given set of functionals.

Some numerical examples

As it is provided in the project, the modelling site is the Tomsk region. The problem is solved in the domain of 100 x 100 km in horizontal dimensions with the center coinciding with the city center. The upper boundary is 700 mb surface.

The horizontal grid size is 1 km. With the use of ISIREMM data the daily behaviour of atmospheric circulation has been simulated. The input meteorological data was taken for 10-11 of February 2001. For the period, the weak (about 5 m/s) background atmospheric flow was observed over the region. The amplitude of the daily surface temperature changes was from 10 to 12 degrees in dependence on the measuring point. The minimum night temperatures were about –25-27°C, and maximum day temperature were about –13-15°C.

The results of simulation are presented at the local time: 0, 3, 6, 9, 12, 15, 18, 21. Figures 1-8 display the horizontal structure of atmospheric circulation at 50m above underlying surface near Tomsk (25x25 km). The river and boundaries of the city settlements are given schematically. The squares denote the point of the domain with the small (with respect to the maximum) wind velocities. The mean velocity in the Tomsk vicinities at this height were 1-3 m/s. Figures 9-16 show the directions of the vertical velocity at 100 m. Vertical bars denote up direction, horizontal bars denote down direction.

As it is seen, the wind structure is formed as a result of interconnection between the relatively weak background flow with the city heat island. The temperature contrasts between the particular parts of the underlying surface have a pronounced effect on the results. The character of the movement changes during the day. As an example, let us pay attention to the area between the central part of the city and Akademgorodok. All the period the downward air fluxes and low wind velocities were calculated for it. In the presence of pollutant sources these facts may promote accumulation of the pollution and formation of high concentration of pollutants. Analysing figs. 3,4,6, one can suppose that accumulated pollution may disperse against the background flow which is predominant in the region. As a result, increased pollution concentration might be observed episodically in Akademgorodok. Decreases of concentration might be determined by the fact that ventilation of Akademgorodok is improved for some periods (figs.5,7).
Fig.1. Time 00.00

Fig.2. Time 03.00

Fig.3. Time 06.00

Fig.4. Time 09.00

Fig.5. Time 12.00

Fig.6. Time 15.00
Publications and papers

Refereed
Penenko V.V., Tsvetova E.A. Numerical models and methods for revealing the risk and vulnerability domains. Computational technologies, 2002 (in press)
Korotkov M.G. Numerical modelling of the daily behaviour of the atmospheric circulation in the Tomsk region Computational technologies, 2002 (in press)

Papers
Tsvetova E.A., Penenko V.V. Adjoint equation and splitting technique for fast data assimilation and
sensitivity studies. The 33rd International Liege Colloquium “The use of data assimilation in coupled hydrodynamics, ecological and bio-geo-chemical models of the ocean”.

MODAS 2001, Irkutsk

Penenko V. Monitoring, diagnosis and forecast of pollutant transport

Penenko V., Tsvetova E. Mathematical models for revealing the domains of increased ecological risk/vulnerability

Tsvetova E., Penenko V. Fast data assimilation in atmospheric and oceanic studies.

Boyarshinova E. Investigation of the algorithms for numerical solution of meso-meteorological problems of atmospheric dynamics over complex relief.

Kurbatskaya L. The model of city heat island in the stable background atmosphere

Pozdnyakova N. Design of numerical model of photochemical oxidation in the atmosphere of industrial regions.

Plan for the next year

WP05

In collaboration with P02, P05 and P06, to describe algorithmically the operators of the models of observations (2) for data assimilation in the fast mode.

WP07

- to couple 3D models for city and regional scales pollutant transport
- to design algorithms of the direct and inverse modelling approaches on the base of the 3D transport models
- to solve the problems of source-receptor and receptor-source types for the modelling site
- to prepare Deliverables D07.1, D07.2

WP10 / Conferences

25th NATO/CCMS International technical meeting on air pollution modelling and its application. 15-19 October, 2001, Louvain-la-Neuve, Belgium (Penenko V.)

MODAS-2, 2002 (5-7 persons)
1. Introduction

1.1 Air quality in urban areas

Major air pollutants in urban areas or the so called “classical pollutants” are: Sulphur dioxide (SO₂), nitrogen dioxide (NO₂), carbon monoxide (CO) and particulate matter (PM). Other pollutants may also be important, for example, the volatile organic compounds (VOC), characterised through the concentration of, for example, benzene or polycyclic aromatic hydrocarbons (PAH), known to have adverse effects in human health such as cancer, or the less dangerous for the health alkanes and aldehydes, extremely important though since they contribute to photo-oxidant or ozone formation. Lead used to be one of the most commonly emitted pollutants but its significance has declined due to the reduced lead contents of gasoline and the introduction of unleaded gasoline in most European countries. Last not least is the ground-level ozone, produced secondarily via chemical reactions of nitrogen oxides and of non-methane volatile organic compounds in the presence of sunlight.

The ambient concentration of air pollutants varies very much in time (daily, weekly and seasonally, following the temporal profile of human activities resulting to air pollutant emissions) and in space. It depends, apart from the morphological and meteorological characteristics of the area concerned, upon the distance from dominating sources and the location within a city. It is made up of the following contributions:

- The natural background contribution;
- The regional background contribution: Long-range transport of anthropogenic emissions, as well as emissions from the cities themselves, leads to a regional increase in the concentration levels of many pollutants and their chemical transformation products;
- The city background contribution: Concentration levels of a number of pollutants are higher in
cities than in the surrounding rural areas. This term refers to the concentration of pollutants at places within cities, not directly influenced by sources such as industry or traffic;

- The traffic or industrial contribution: In busy streets and near industrial sources, the concentration field is further elevated through nearby emissions. “Traffic” or “industrial” concentrations refer to the concentration of pollutants at places directly influenced by traffic or industry, the so-called “hot-spots”.

Especially high concentrations, so called “episodes” with a life-time of a few days, are observed in urban areas when the large-scale synoptic weather situation is unfavourable for dispersion and deposition and enhanced regional concentrations are present. Commonly, winter-type smog episodes occur during spells of cold winter weather when a high pressure system persists for several days. Dispersion is limited due to low wind speeds and a marked subsidence inversion. Winter-type air pollution episodes are generally characterised by high concentrations of sulphur dioxide (SO₂) and particulate matter (PM), mainly due to increased use of, and subsequent emissions from, fossil fuels for space/domestic heating. Summer-type smog episodes occur during warm and sunny weather in the summer season. Under the influence of sunlight, ozone is formed from nitrogen oxides and volatile organic compounds. At the same time the concentrations of other secondary formed compounds are increased as well as those from primarily emitted compounds such as traffic emissions.

The Tomsk area represents a “good” example of an industry driven air pollution problem, while also being known as an area of high potential for technological plant accidents (Tcherkezian et al., 1993).

The actual occurrence and frequency of increased air pollution concentrations depends primarily on the magnitude and the distribution of emission sources, on local topography (e.g., flat terrain, basin or valley) as well as on the local meteorology (e.g., average wind speed, frequency of calm weather conditions, occurrence of inversion layers) which determines the degree of pollutant dispersion and mixing with cleaner air after the emission took place;

Following the above, it is apparent that the problem of air quality management should be dealt with in a way capable of addressing the complexities of interactions between the various physical, ecological, socio-economic and political aspects, components and actors related with urban air quality, thus posing a considerable challenge to planners, policy and decision makers and the general public. Moreover, there should be a distinction between the problems that urban air quality management is dealing with and between problems of a more generalised scale like climatic change. Climatic change, resulting from global warming (a problem resulting from the emissions of the “Greenhouse gases”), is a global environmental problem that is related to, but certainly not covered by urban air quality management.

1.2 Assessing and managing urban air quality: The use of models

In air pollution assessments information on all parts of the cause-effect chain have to be collected. Not only a physical/chemical description of ambient air has to be presented in such a way that it can be compared with effect threshold values, but also the relation between this effect quantity and the atmospheric emissions from sources (e.g. source categories, countries, regions, economical sectors) should be quantified. For an optimal abatement strategy to be developed it is essential that all three elements, (threshold or critical values, ambient parameters and emissions) are available. Three types of instruments are used in assessment studies: emission inventories (as a

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prerequisite for linking anthropogenic activities with air emissions), air quality field measuring programmes and atmospheric dispersion and transport models.

Field measurements form an important aspect of a system aiming at the description of air pollution patterns in a given domain. Yet, observations are made at a limited number of locations which are not necessarily representative for the entire area of interest. Mathematical models may therefore prove useful for establishing consistent mass budgets of emission, transport, transformation, and deposition of pollutants.

There are several examples for previous numerical simulations of air pollutant transport and transformation in the local-to-regional scale which, broadly speaking, corresponds to the mesoscale\textsuperscript{13}. In this context, it has already been recognized that urban scale problems can only be treated successfully by the aid of mesoscale air pollution models if either a large enough domain is considered or accurate boundary conditions are established. Air pollution models require at input considerable meteorological information. In the last years, two different approaches were followed in this respect: Diagnostic wind field calculation, in conjunction with an empirical parameterisation for turbulence quantities, and prognostic calculation of both wind fields and turbulence quantities. The former approach presupposes the availability of very detailed observed data which would allow an accurate wind field reconstruction\textsuperscript{14}. This, however, is under normal circumstances not feasible. Therefore, the latter approach, i.e. the numerical simulation of the wind and turbulence patterns in the area of interest, is nowadays widely preferred.

Both Eulerian and Lagrangian model types are being employed to describe the dispersion of inert pollutants. Eulerian dispersion models predominate in the case of reactive pollutants, typically ozone and its precursors\textsuperscript{15}. Here it is usual practice to apply the wind model first and the (photochemical) dispersion model subsequently.

In prognostic mesoscale models the large scale (temporal and spatial) distribution of all problem variables is assumed to be known and is used to define initial and boundary conditions. Major aim of these models is to describe how the problem variables are affected by mesoscale influences (e.g. those associated with orography and inhomogeneities in the surface energy balance). As a minimum requirement for a realistic simulation of air pollutant transport in the local-to-regional scale, a prognostic mesoscale air pollution model should include a reasonable parameterization with regard to the dynamics of the atmospheric boundary layer. The latter depends on the turbulence characteristics which may vary with both height and time.

Prognostic mesoscale models differ with regard to the treatment of pressure. If the characteristic horizontal length scale is larger than 10 km, nonhydrostatic effects (and thus also dynamical vertical accelerations) may be neglected. In models adopting this approach, the so-called hydrostatic models, pressure can be simply obtained from the hydrostatic equation. On the contrary, in nonhydrostatic models the elliptic differential equation for pressure has to be solved. Nowadays efficient elliptic solvers are available, and so the overall computational demand of a nonhydrostatic model is not much higher than that of a hydrostatic model.


In most of the contemporary prognostic mesoscale models a transformation to terrain-influenced co-ordinates is performed to avoid difficulties in the formulation of the boundary conditions at surface. Regarding the impact of the surface on wind flow and dispersion characteristics, special care has to be taken to describe urban scale processes. Such processes are in general much more complex than those at larger scales: Buildings and other obstructions lead to very complex wind flow patterns in an urban area, while the presence of large concentration gradients within cities makes it extremely difficult to find representative locations for air quality monitoring stations. Additional difficulties may arise from the typical intermittency of air pollutant concentrations in an urban area and from the strong impact that concentration fluctuations may have with regard to chemical reactions occurring in an urban airshed.

Details on the overall structure of prognostic mesoscale models are given in several previous articles and books16.

The air pollution model system used in the frame of ISIREMM was developed AUT and represents one of the most widely utilized European model systems developed for the description of local-to-regional dispersion and chemical transformation processes17 (Moussiopoulos, 1995b, Moussiopoulos et al., 1993, Kunz and Moussiopoulos, 1995). In its present version, the model system takes fully into account the manifold interactions between the various scales influencing the pollution patterns in the airshed considered and comprises of the models MEMO and MUSE, described in detail in next sections.

2. Implementation of the air quality modelling system

2.1 The non-hydrostatic mesoscale prognostic 3-D model MEMO

Wind flow will be simulated with MEMO, one of the core models of the European Zooming Model (EZM) which belongs to the family of models designed for describing atmospheric transport phenomena in the local-to-regional scale. EZM was developed for the refined modelling of transport and chemical transformation of pollutants in selected European regions in the frame of the EUROTRAC subproject EUMAC (therefore its previous name EUMAC Zooming Model). In the meantime the EZM has evolved to be one of the most frequently applied mesoscale air pollution modelling systems in Europe. Thus, it has already been successfully applied for various European airsheds including the Upper Rhine Valley and the areas of Heilbronn, Basel, Graz, Barcelona, Lisbon, Madrid, Milano, London, Cologne, Lyon, The Hague and Athens18.

16 Pielke R. A. (1984), Mesoscale Meteorological Modelling, Academic Press,
Moussiopoulos N., Flasak Th., Sahm P. and Berlowitz D. (1993), Simulations of the wind field in Athens with the nonhydrostatic mesoscale model MEMO, Environmental Software 8, 29-42.
MEMO is a physically complete non-hydrostatic mesoscale model which allows performing multiple nested grid simulations. Within MEMO, the conservation equations for mass, momentum and scalar quantities such as potential temperature, turbulent kinetic energy and specific humidity are solved. The governing equations are solved in terrain-influenced coordinates on a staggered grid arrangement allowing for non-equidistant grid spacing in all directions.

As an important feature of MEMO, conservative properties are fully preserved within the discrete model equations. The discrete pressure equation is solved with a fast elliptic solver in conjunction with a generalised conjugate gradient method. Advection terms are treated with a total-variation-diminishing scheme. Turbulent diffusion is described with an one-equation turbulence model (conservation equation for the turbulent kinetic energy and algebraic equation for the mixing length). At roughness height similarity theory is applied. The radiative heating/cooling rate in the atmosphere is calculated with an efficient scheme based on the emissivity method for longwave radiation and an implicit multilayer method for shortwave radiation. The surface temperature over land is computed from the surface heat budget equation. The soil temperature is calculated by solving an one dimensional heat conduction equation. At lateral boundaries generalised radiation conditions are imposed.

2.2 The photochemical dispersion model MUSE

Air pollution in the Tomsk area will be studied with the multilayer photochemical dispersion model MUSE, which is one of the core models of the EZM. The EZM system is a complete system for simulating the wind flow and pollutant transport and transformation in the mesoscale as described previously. Main modules of the EZM are the nonhydrostatic mesoscale model MEMO (see above), the photochemical dispersion model MARS19 and the multilayer dispersion model MUSE20 which was developed as a simplified version of the 3-D dispersion model MARS.

MUSE is a multilayer Eulerian photochemical dispersion model for inert and reactive species in the local-to-regional scale. The atmospheric boundary layer is divided into individual layers; the thickness of each layer is allowed to vary in the course of the day in order to adequately simulate the dynamics of the atmospheric boundary layer. In this study five layers have been used. A shallow layer adjacent to the ground is defined for the proper simulation of dry deposition and other sub-grid phenomena. The upper limit of the second layer is defined at a height equal to the half of the mixing height. The latter is described by Deardorff’s prognostic equation21 which was shown to lead to realistic results when the variation of the mixing height with time is strongly influenced by surface heating22. The upper limits of the third and the fourth layer are defined by the lower and


19 Moussiopoulos N. (1989), Mathematische Modellierung mesoskaliger Ausbreitung in der Atmosphäre, Fortschr.-Ber, VDI Reihe 15, Nr. 64, VDI-Verlag, Düsseldorf.


upper limit of the entrainment zone. The top of the upper layer, which serves as a reservoir layer, is fixed to an altitude of 3000 m.

Advective transport is described with the scheme of Smolarkiewicz. The average wind speed in each of the five layers is calculated by integrating the fluxes of the corresponding layers of the fully 3-D wind field computed by the model MEMO.

The differential equation system in MUSE is solved with a backward difference solution procedure, i.e. by applying the Gauss-Seidel iteration scheme. Because of the nature of this semi-implicit algorithm, vertical diffusive transport and chemical transformation of pollutants have to be treated separately. In view of the feasible error caused by splitting the operators associated with vertical diffusion and chemistry, the justification for this separate treatment should be controlled by the aid of selected applications of the implicit version of MARS.

In order to proceed with model calculations in the Tomsk area, an appropriate configuration and set-up should be made. For this reason, a number of preparatory actions were undertaken from the modelling point of view during the first year of the project, in order to set-up and test the software of the MEMO and MUSE models and to screen and provide with the necessary input requirement information to the data providing partners. For this reason, the following chapters describing the MEMO and MUSE model requirements were prepared and were forwarded to IAO/Russia.

3. MEMO model: Input requirements

3.1 General Information

General information about the MEMO model can be found at in the Model Documentation System of the European Topic Centre on Air Quality/European Environment Agency:

http://155.207.20.121/mds/bin/allmodels

3.2 Input Data

3.2.1 Topography and Surface Type

For calculations with MEMO a file must be provided which contains orography height and surface type for each grid location (i, j) with i = 2, ..., IM+1; j = 2, ..., JM+1. IM and JM are the numbers of grid points in x- and y-direction. The x-axis (index i) must be directed to the western direction and the y-axis (index j) to the northern direction. The gridpoint (2,2) is in the SW-corner of the computational domain. The meshes at I=1, I=IM+2, J=1 and J=JM+2 are pure computing meshes.


necessary to reach good vectorization.

The following surface types are distinguished and must be stored as percentage in the array \( LU(I,J,L) \).

<table>
<thead>
<tr>
<th>L</th>
<th>designation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>water</td>
</tr>
<tr>
<td>2</td>
<td>arid land</td>
</tr>
<tr>
<td>3</td>
<td>few vegetation</td>
</tr>
<tr>
<td>4</td>
<td>farmland</td>
</tr>
<tr>
<td>5</td>
<td>forest</td>
</tr>
<tr>
<td>6</td>
<td>suburban area</td>
</tr>
<tr>
<td>7</td>
<td>urban area</td>
</tr>
</tbody>
</table>

Only surface types 1 - 6 have to be stored. Type 7 is the difference between 100% and the sum of types 1 - 6 (cf. Appendix A). If the percentage of a surface type is 100%, then write the number 10 and for all other surface types the number 99.

The orography height is the mean height for each grid location \((i,j)\) above sea level in meter.

The input format and the meaning of the variables are given in Appendix A.

### 3.2.2 Meteorological Input

For simulations control additional information is required according to appendix B.

The prognostic model MEMO is a set of partial differential equations in 3 spatial directions and in time. To solve these equations information about the initial state in the whole domain and about the development of all relevant quantities at the lateral boundaries is required.

#### 1) Initial state

To generate an initial state for the prognostic model a diagnostic model is applied using measured temperature and wind data. Both, temperature and wind data can be provided as:

a) surface measurements i.e. single measuring directly above the surface (not necessary)

b) upper air soundings i.e. soundings that consist of several (at least two) measurements at different height levels at a constant geographical location (at least one sounding for temperature and wind velocity is necessary)

In Appendix D a list of all input variables is given. Appendix E gives an example for an input file.

#### 2) Timedependant boundary conditions

Information about quantities at the lateral boundaries can be taken into account as surface measurements and upper air soundings. Therefore, a key word and the time when boundary data is given must occur in front of a set of boundary information. The same input format is used as to provide initial state data. A sample file is given in Appendix E.

### 4. Muse model: Input requirements

A prerequisite for the application of the model MUSE is the availability of the three-dimensional wind field and of the necessary emission data.

#### 4.1 Topography and Meteorological Data

For calculations with MARS a file must be provided which contains orography height for each grid location \((i, j)\) with \(i = 1, \ldots, IM\); \(j = 1, \ldots, JM\). IM and JM are the numbers of grid points in x- and y-direction. The x-axis (index i) must be directed to the western direction and the y-axis (index j) to the northern direction. The gridpoint \((1,1)\) is in the SW-corner of the computational domain. The
orography height is the mean height for each grid location \((i,j)\) above sea level in meter.

Meteorological data such as wind speed in \(x\)- and \(y\)-direction \((U,V)\) as well as the turbulent kinetic energy, surface roughness, Monin-Obukhov-Length and friction velocity are requested as input at pre-defined times during the model simulation. Between individual input times a temporal interpolation is performed.

The gridsize of the meteorological data set must coincide with the gridsize of the MUSE grid. However, the meteorological data grid may be larger than the MUSE grid, to correctly allocate the meteorological data, use the ISTART, JSTART indicator. To ensure a mass-consistent wind field, the meteorological quantities must follow the grid notation of the staggered grid.

The input format and the meaning of the variables are given in Appendix A-1.

### 4.2 Emission Data

The diurnal cycle of all emitters taken into account in the reaction scheme and the composition of every single pollutant source is necessary to compile an appropriate emission inventory (EI) for the dispersion calculations. To provide the EI, the EMIZ standard format is used. The structure and the meaning of the variables of this file are given in Appendix B. Here only a brief overview on the emitters which should be included in the EI and the use of the EI in the MARS model is given.

In the EI fourteen species (which must be supplied in the following order) are taken into account:

1. Nitrogen monoxide (NO)
2. Nitrogen dioxide (NO\(_2\))
3. Carbonmonoxide (CO)
4. Butane
5. Pentane
6. Hexane
7. Toluene
8. Xylene
9. Formaldehydes
10. Higher Aldehydes
11. Ethene
12. Propen
13. Butene
14. Methane

The MUSE model calculates concentrations in the unit \(ppb\) whereas the emissions should be compiled in \(kg/(km^2h)\). The values are converted internally to \(ppb/s\) for the computational grid.

For the calculation with the KOREM mechanism, the VOCs are lumped in five classes, i.e.:

- Methane (METH) including \(C_nH_{2n+2} ; n\leq3\)
- Alkanes (ALK) including \(C_nH_{2n+2} ; n\geq4\)
- Alkenes (OLE) including \(C_nH_{2n}\)
- Aromatics (ARO) i.e. Benzene, Toluene and higher aromatics
- Aldehyds (RCHO) i.e. Formaldehyde and higher aldehydes

**Temporal resolution of emissions:** Between individual input times a temporal interpolation is
Spatial allocation of emissions: The gridsize of the emission data set must coincide with the gridsize of the MARS grid. However, the emission grid may be larger than the MARS grid, to correctly allocate the emission data, use the ISTAEM, JSTAEM indicator as described in Appendix A-2.

4.3 Initial and Boundary Conditions

The model MUSE is a set of partial differential equations in 3 spatial directions and in time. To solve these equations information about the initial state in the whole domain and about the development of all pollutant concentrations at the lateral boundaries is required.

1) Initial state

Information about initial pollutant concentrations can be taken into account at different height levels than those provided with the meteorological data.

2) If the external boundary indicator IBCEXT is specified as (1), constant lateral boundary conditions can be provided at different height levels.

3) External time dependent boundary conditions can be specified via the IBCEXT indicator (=2) described in Appendix A-3.

The structure and the meaning of the variables of this external boundary conditions file are given in Appendix A-3.

WP04: Research Results

Following the tasks planned according to the ISIREMM Technical Annex, AUTH/LHTEE compiled the air quality model framework as described above and made various tests, in order to be able to proceed with the simulations during the next reporting period. Although simulations were scheduled to start during the first project period, it was proven to be more efficient to invest more time in the preparations of the modelling infrastructure. This, however, does not influence the overall progress of the project work.

AUTH/LHTEE provided with the necessary information to the partners involved in the modelling task. Due to some delays in the response of these partners, AUTH/LHTEE could not use man-month resources allocated as internally planned, and had to change the time frame of performing the simulations as a result of internal personnel reallocation. Nevertheless, tasks will continue according to Technical Annex. It should also be noted that, following the experience of the ECOSIM project, upon which the ISIREMM architecture is based, AUT/LHTEE investigated new features like the introduction of XML structures in the modelling module, in order to make it compatible to the ISIREEM architecture.

Plans for the next reporting period

AUTH/LHTEE plans to finalize (with the aid of collaborating partners) the selection of the scenarios to be studied, and to perform the simulations.

More specifically, AUTH/LHTEE will complete the study of the meteorological and emission scenario parameters, and will select a number of related scenarios that represent in an optimum way the air quality problem of the Tomsk Greater Area. As the latter is located in an industrial Siberian region, the main focus will be on industrial and central heating related emission scenarios. Modifications might be required regarding the treatment of some of the physical parameters in the air quality modelling, due to extreme weather conditions. It should be noted that there are very few AQ simulation studies available for regions such as the one studied in ISIREMM.

After the selection of the scenarios, AUT/LHTEE will compile the simulations and modify results so that can be fitted in the ISIREMM system.
A number of scientific publications is also among the goals for the next reporting period.

**Appendices**

**Appendix A**

Reading simulation data

```fortran
READ (2,`'(A60)`) COM1
READ (2,`'(3I3,6F8.0)`) IDUM, IM1, JM1, XDX, XDY, XDUM1, XDUM2, ZABS, DZISO
READ (2,`'(A60)`) FOR1
READ (2,`'(A60)`) FOR2

DO 30 J = 2,JM+1
READ (2,FOR1) LU(I,J,L,L=1,6),I = 2,IM+1)
30 CONTINUE

DO40 J = 2,JM+1
READ (2,FOR2) (ZS(I,J),I = 2,IM+1)
40 CONTINUE
```

<table>
<thead>
<tr>
<th>Variable</th>
<th>Type / Dimension</th>
<th>Unit</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>COM1</td>
<td>Character*60 / 1</td>
<td>-</td>
<td>Comment card</td>
</tr>
<tr>
<td>IDUM</td>
<td>Integer / 1</td>
<td>-</td>
<td>Dummy variable</td>
</tr>
<tr>
<td>IM1/ JM1</td>
<td>Integer / 1</td>
<td>-</td>
<td>Number of grid points in x/y-direction (without boundary points)</td>
</tr>
<tr>
<td>XDX/ XDY</td>
<td>Real / 1</td>
<td>m</td>
<td>Gridspacing in x/y-direction</td>
</tr>
<tr>
<td>XDUM1/ XDUM2</td>
<td>Real / 1</td>
<td>-</td>
<td>Dummy variables</td>
</tr>
<tr>
<td>ZABS</td>
<td>Real / 1</td>
<td>m</td>
<td>Used only for plotting of orography: Base isoplet value</td>
</tr>
<tr>
<td>DZISO</td>
<td>Real / 1</td>
<td>m</td>
<td>Used only for plotting of orography: contour interval</td>
</tr>
<tr>
<td>FOR1</td>
<td>Character*60 / 1</td>
<td>-</td>
<td>FORTRAN format used to read the LU-array, e.g.: <code>(6(1X,6I2))</code></td>
</tr>
</tbody>
</table>
Appendix B
From the FORTRAN standard input device data is read using the following FORTRAN notation. Required input are marked red.

```fortran
READ (5,*) VERS
READ (5,`(A60)`) COM2
READ (5,*) INHYD
READ (5,*) IHYDNL
READ (5,*) ITURB
READ (5,*) IART,IPHI
READ (5,*) DT
READ (5,*) SECMAX
READ (5,*) IPR,TTPR,TDPR
READ (5,*) IMMPR,TTMMPR,TDMMPR
READ (5,*) JLMAX,(JPRI(JL), JL=1,JLMAX)
READ (5,*) ILMAX,(IPRI(IL), IL=1,ILMAX)
READ (5,*) ZT,HHMIN
READ (5,*) MONTH,DAY,YEAR
READ (5,*) LATI,LONG,TZME
READ (5,*) CL
READ (5,*) TSTART,XKMIN,XKMIN
READ (5,*) IRRUN,ISTORE
READ (5,*) DREAD,DWRITE
READ (5,*) INESI,INESO
READ (5,*) DTNESS
READ (5,*) XZERO,YZERO,XNEST
```

27If the percentage of a surface type is 100% then write the number 10 and for all other surface types the number 99
READ (5,*) IREW, TTREW, TDREW  
READ (5,*) IUNI, TTUNI, TDUNI  
READ (5,*) IUNP, TTUNP, TDUNP  
READ (5,*) IWRI, TTWRI, TTDWRI  
READ (5,*) ICON, TTCOM, TTDCON  
READ (5,*) ITRA, NPART, TTTRA, TWTRA, TWTRA, TSTRA, TSDTRA  
READ (5,*) (XPART(I,1), I=1, NPART)  
READ (5,*) (XPART(I,2), I=1, NPART)  
READ (5,*) (XPART(I,3), I=1, NPART)  
READ (5,*) TIJMAX, (TIJ(J,1), J=1, TIMAX)  
READ (5,*) (TIJ(J,2), J=1, TIMAX)  
READ (5,*) TSW, TSOIL, ZSSOIL  
READ (5,*) (Z0I(J), J=1, LMAX)  
READ (5,*) (T0I(J), J=1, LMAX)  
READ (5,*) (ALBI(J), J=1, LMAX)  
READ (5,*) (ROCBOI(J), J=1, LMAX)  
READ (5,*) (FPARAI(J), J=1, LMAX)  
READ (5,*) (KBI(J), J=1, LMAX)  
READ (5,*) IIRIS  
IF (IIRIS.NE.1) THEN  
  READ (5,*) DTUPD, IUPDM  
  DO 10 J=1, LMAX  
    READ (5,*) (DTDTI(L, J), L=1, IUPDM)  
  10  CONTINUE  
END IF

<table>
<thead>
<tr>
<th>Variable</th>
<th>Type / Dimension</th>
<th>Unit</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>VERS</td>
<td>Real / -</td>
<td>-</td>
<td>Version-No. (Position 10-16 in this line must be 'VERSION')</td>
</tr>
<tr>
<td>COM2</td>
<td>Character*60 / 1</td>
<td>-</td>
<td>Comment card</td>
</tr>
</tbody>
</table>
| INHYD    | Integer / 1      | -    | Indicator for a non-hydrostatic or a hydrostatic run  
            |       |         | = 1: non-hydrostatic  
<pre><code>        |       |         | ≠ 1: hydrostatic |
</code></pre>
<table>
<thead>
<tr>
<th>Variable</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>IHYDNL</td>
<td>Integer</td>
<td>Indicator for the subroutine called to compute the hydrostatic pressure:</td>
</tr>
<tr>
<td></td>
<td>/ 1</td>
<td>-0: HYD3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-1: HYD3NL</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-2: HYD4NL</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(IHYDNL = 1 recommended)</td>
</tr>
<tr>
<td>ITURB</td>
<td>Integer</td>
<td>Indicator for applied turbulence model:</td>
</tr>
<tr>
<td></td>
<td>/ 1</td>
<td>-1: algebraic function for exchange coefficients using Pandolfo's approach</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-2: algebraic function derived from the one-equation turbulence model</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-3: one-equation turbulence model (=1 partial differential equation for turbulent kinetic energy E)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-4: two-equation turbulence model (=2 partial differential equations for turbulent kinetic energy E and dissipation rate)</td>
</tr>
<tr>
<td>IART</td>
<td>Integer</td>
<td>Indicator for artificial diffusion:</td>
</tr>
<tr>
<td></td>
<td>/ 1</td>
<td>-0: artificial diffusion not taken into account</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-1: artificial diffusion for velocity and scalar quantities taken into account not depending on the shortwave radiation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-2: equivalent to IART=1 but artificial diffusion of scalar quantities depending on shortwave radiation</td>
</tr>
<tr>
<td>IPHI</td>
<td>Integer</td>
<td>Indicator for calculation of turbulent mixing length:</td>
</tr>
<tr>
<td></td>
<td>/ 1</td>
<td>-0: turbulent mixing length formula of Blackadar</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-1: turbulent mixing length corrected by the influence of the thermal stability</td>
</tr>
<tr>
<td>DT</td>
<td>Real</td>
<td>Timestep (If DT&lt;0, automatic time control is enabled)</td>
</tr>
<tr>
<td>SECMAX</td>
<td>Real</td>
<td>Simulation period</td>
</tr>
<tr>
<td>IPR</td>
<td>Integer</td>
<td>Indicator for printout size (0 - 6 are valid)</td>
</tr>
<tr>
<td>TTPR</td>
<td>Real</td>
<td>Initial printout time</td>
</tr>
<tr>
<td>TDPR</td>
<td>Real</td>
<td>Printout increment</td>
</tr>
<tr>
<td>IMMPr</td>
<td>Integer</td>
<td>Indicator for printout of max-min-values:</td>
</tr>
<tr>
<td></td>
<td>/ 1</td>
<td>-0: no printout</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-1: printout</td>
</tr>
<tr>
<td>TTMMPr</td>
<td>Real</td>
<td>Initial printout timestep of max-min-values</td>
</tr>
<tr>
<td>Variable</td>
<td>Type</td>
<td>Description</td>
</tr>
<tr>
<td>-----------</td>
<td>--------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>TDMMPR</td>
<td>Real  / 1 sec</td>
<td>printout increment of max-min-values</td>
</tr>
<tr>
<td>JLMAX</td>
<td>Integer / 1</td>
<td>max. numbers of printed x,z-cross sections</td>
</tr>
<tr>
<td>JPRI</td>
<td>Integer / JLMAX</td>
<td>index of the JLMAX printed x,z-cross sections</td>
</tr>
<tr>
<td>ILMAX</td>
<td>Integer / 1</td>
<td>max. numbers of printed y,z-cross sections</td>
</tr>
<tr>
<td>IPRI</td>
<td>Integer / ILMAX</td>
<td>index of the ILMAX printed y,z-cross sections</td>
</tr>
<tr>
<td>ZT</td>
<td>Real  / 1 m</td>
<td>upper boundary height</td>
</tr>
<tr>
<td>HHMIN</td>
<td>Real  / 1 m</td>
<td>min. grid spacing in vertical direction in the lowermost computational gridcell</td>
</tr>
<tr>
<td>MONTH</td>
<td>Real  / 1</td>
<td>month of simulation</td>
</tr>
<tr>
<td>DAY</td>
<td>Real  / 1</td>
<td>day of simulation</td>
</tr>
<tr>
<td>YEAR</td>
<td>Real  / 1</td>
<td>year of simulation (e.g. 92)</td>
</tr>
<tr>
<td>LATI</td>
<td>Real  / 1 degree</td>
<td>Latitude</td>
</tr>
<tr>
<td>LONG</td>
<td>Real  / 1 degree</td>
<td>Longitude</td>
</tr>
<tr>
<td>TZME</td>
<td>Real  / 1 degree</td>
<td>Time zone meridian</td>
</tr>
<tr>
<td>CL</td>
<td>Integer / 6</td>
<td>Cloud data. Each element of the array CL has the form LCL<em>100+TCL</em>10+ECL with:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>LCL  Level of cloud layer</td>
</tr>
<tr>
<td></td>
<td></td>
<td>TCL  Cloud type</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(1: Fog, 2: St, 3: Sc, 4: Cu, 5: Cb, 6: As, 7: Ac, 8: Cl, 9: Cs)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ECL  Amount in eighths</td>
</tr>
<tr>
<td>TSTART</td>
<td>Real  / 1 hour</td>
<td>simulation start time</td>
</tr>
<tr>
<td>XKKMIN</td>
<td>Real  / 1 m²/s</td>
<td>min. exchange coefficient for momentum</td>
</tr>
<tr>
<td>XKTKMIN</td>
<td>Real  / 1 m²/s</td>
<td>min. exchange coefficient for scalars</td>
</tr>
<tr>
<td>IRRUN</td>
<td>Integer / 1</td>
<td>Indicator for reading all relevant quantities at the beginning of the run from a file (=recover run)</td>
</tr>
<tr>
<td>ISTORE</td>
<td>Integer / 1</td>
<td>Indicator for writing all relevant quantities at the end of a run on a file (to have the possibility to continue the run later as recover run (cf. IRRUN-Indicator))</td>
</tr>
<tr>
<td>DREAD</td>
<td>Character*30 / 1</td>
<td>filename for recover read file</td>
</tr>
<tr>
<td>Variable</td>
<td>Type</td>
<td>Units</td>
</tr>
<tr>
<td>----------</td>
<td>---------</td>
<td>-------</td>
</tr>
<tr>
<td>DWRITE</td>
<td>Character*30 / 1</td>
<td>-</td>
</tr>
</tbody>
</table>
| INESI    | Integer / 1 | -     | Indicator for a nesting run: A coarse grid file will be read  
=1: boundary values are specified with expanded radiation conditions  
=2: boundary values are specified with a relaxation scheme |
<p>| INESO    | Integer / 1 | -     | Indicator for a nesting run: stores the data for a consecutive fine grid run |
| DTNESS   | Real / 1 | sec   | Time increment for CG- nesting output |
| XZERO    | Real / 1 | m     | Origin of fine grid domain within coarse grid domain x-direction |
| YZERO    | Real / 1 | m     | Origin of fine grid domain within coarse grid domain y-direction |
| XNEST    | Real / 1 | -     | Ratio of grid spacing between coarse and fine grid |
| IREW     | Integer / 1 | -     | cf. Appendix F |
| TTREW    | Real / 1 | sec   | &quot;-&quot; |
| TDREW    | Real / 1 | sec   | &quot;-&quot; |
| IUNI     | Integer / 1 | -     | cf. Appendix G |
| TTUNI    | Real / 1 | sec   | &quot;-&quot; |
| TDUNI    | Real / 1 | sec   | &quot;-&quot; |
| IUNP     | Integer / 1 | -     | cf. Appendix H |
| TTUNP    | Real / 1 | sec   | &quot;-&quot; |
| TDUNP    | Real / 1 | sec   | &quot;-&quot; |
| IWRI     | Integer / 1 | -     | cf. Appendix K |
| TTWRI    | Real / 1 | sec   | &quot;-&quot; |
| TTDWRI   | Real / 1 | sec   | &quot;-&quot; |
| ICON     | Integer / 1 | -     | cf. Appendix L |
| TCON     | Real / 1 | sec   | &quot;-&quot; |
| TTDCON   | Real / 1 | sec   | &quot;-&quot; |
| ITRA     | Integer / 1 | -     | cf. Appendix I |
| NPART    | Integer / 1 | -     | &quot;-&quot; |
| TTRAF    | Real / 1 | sec   | &quot;-&quot; |
| TWTRA    | Real / 1 | sec   | &quot;-&quot; |
| TWDTRA   | Real / 1 | sec   | &quot;-&quot; |</p>
<table>
<thead>
<tr>
<th>Variable</th>
<th>Type / Dimensions</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>TSTRA</td>
<td>Real / 1 sec</td>
<td>-</td>
</tr>
<tr>
<td>TSDTRA</td>
<td>Real / 1 sec</td>
<td>-</td>
</tr>
<tr>
<td>XPART</td>
<td>Real / NPART,3 m</td>
<td>-</td>
</tr>
<tr>
<td>TIJMAX</td>
<td>Integer / 1</td>
<td>-</td>
</tr>
<tr>
<td>TIJ</td>
<td>Integer / 10,2</td>
<td>-</td>
</tr>
<tr>
<td>TSW</td>
<td>Real / 1 C</td>
<td>Water temperature</td>
</tr>
<tr>
<td>TSOIL</td>
<td>Real / 1 C</td>
<td>Soil temperature 2 m below surface</td>
</tr>
<tr>
<td>ZSSOIL</td>
<td>Real / 1 m</td>
<td>Topographic height at location of TSOIL</td>
</tr>
<tr>
<td>Z0I</td>
<td>Real / LMAX m</td>
<td>Roughness height of L&lt;sup&gt;th&lt;/sup&gt; surface type</td>
</tr>
<tr>
<td>T0I</td>
<td>Real / LMAX C</td>
<td>Initial potential surface temperature of L&lt;sup&gt;th&lt;/sup&gt; surface type</td>
</tr>
<tr>
<td>ALBI</td>
<td>Real / LMAX</td>
<td>Shortwave albedo of the L&lt;sup&gt;th&lt;/sup&gt; surface type</td>
</tr>
<tr>
<td>ROCBOI</td>
<td>Real / LMAX J/(m K)</td>
<td>Volumetric soil capacity of L&lt;sup&gt;th&lt;/sup&gt; surface type</td>
</tr>
<tr>
<td>FPARAI</td>
<td>Real / LMAX</td>
<td>Evaporation parameter (0 ≤ FPARAI(1,...,7) ≤ 1)</td>
</tr>
<tr>
<td>KBI</td>
<td>Real / LMAX m²/s</td>
<td>Thermal soil diffusivity of L&lt;sup&gt;th&lt;/sup&gt; surface type</td>
</tr>
</tbody>
</table>
| IIRIS    | Integer / 1       | Indicator for surface temperature and heating/cooling rate within the atmosphere with IRIS or prescribe surface temperature with DTDTI-array  
= 1: IRIS  
= 0: using DTDTI-array, no heating-cooling rate |
| DTUPD    | Real / 1 hour     | Update interval of the DTDTI-array (only relevant if IIRIS = 0) |
| IUPDM    | Integer / 1       | Number of rows of the DTDTI-array (only relevant if IIRIS = 0)  
If a run is not finished after IUPDM*DTUPD hours the array DTDTI is used another time right from the beginning. |
| DTDTI    | Real / 50,LMAX K  | Temperature change during the DTUPD hours of the L<sup>th</sup> subsurface type (only relevant if IIRIS = 0) |
Appendix C

This is an example for an area with 30x36x35 grid points and a grid spacing in horizontal direction of 2.5 km (based on appendix B)

<table>
<thead>
<tr>
<th>INPUT DATA</th>
<th>VARIABLE NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.0</td>
<td>VERSION</td>
</tr>
<tr>
<td>TESTSIMULATION ATHENS 30<em>36</em>35, 12 HOURS</td>
<td>COM2</td>
</tr>
<tr>
<td>1</td>
<td>INHYD</td>
</tr>
<tr>
<td>1</td>
<td>IHYDNL</td>
</tr>
<tr>
<td>3</td>
<td>ITURB</td>
</tr>
<tr>
<td>1 0</td>
<td>IART,IPHI</td>
</tr>
<tr>
<td>15.0</td>
<td>DT</td>
</tr>
<tr>
<td>86400.</td>
<td>SECMAX</td>
</tr>
<tr>
<td>1 3600. 3600.</td>
<td>IPR, TTPR, TDPR</td>
</tr>
<tr>
<td>1 3600. 3600.</td>
<td>IMMPR, TTMMPR, TDMMPR</td>
</tr>
<tr>
<td>1 15</td>
<td>JLMAX, JLOC(1...JLMAX)</td>
</tr>
<tr>
<td>1 15</td>
<td>ILMAX, ILOC(1...ILMAX)</td>
</tr>
<tr>
<td>6000. 20.</td>
<td>ZT, HHMIN</td>
</tr>
<tr>
<td>7.0 1.0 92.</td>
<td>MONTH, DAY, YEAR</td>
</tr>
<tr>
<td>38. 23.7 30.</td>
<td>LATI, LONG, TZME</td>
</tr>
<tr>
<td>0 0 0 0 0 0 0</td>
<td>CL(J) (CLOUD DATA)</td>
</tr>
<tr>
<td>0.0 0.5 0.0</td>
<td>TSTART, XKMMIN, XKTMIN</td>
</tr>
<tr>
<td>0 1</td>
<td>IRRUN, ISTORE</td>
</tr>
<tr>
<td>RECO.DAT RECO.DAT DREAD, DWRITE</td>
<td></td>
</tr>
<tr>
<td>0 1</td>
<td>INESI, INESO</td>
</tr>
<tr>
<td>15.</td>
<td>DTNESS</td>
</tr>
<tr>
<td>35000. 25000. 2.5</td>
<td>XZERO, YZERO, XNEST</td>
</tr>
<tr>
<td>1 3600. 3600.</td>
<td>IREW, TTREW, TDREW (UNIT 10 - FILE)</td>
</tr>
<tr>
<td>1 3600. 3600.</td>
<td>IUNI, TTUNI, TDUNI (UNIT 20 - FILE)</td>
</tr>
<tr>
<td>0 3600. 3600.</td>
<td>IUNP, TTUNP, TDUNP (UNIT 21 - FILE)</td>
</tr>
<tr>
<td>1 60. 60.</td>
<td>IWRI, TTWRI, TDWRI (UNIT 66 - FILE)</td>
</tr>
<tr>
<td>1 3600. 3600.</td>
<td>ICON, TTCON, TTDCON (UNIT 77 - FILE)</td>
</tr>
<tr>
<td>1 6 1440. 1440. 48. 1440. 12.</td>
<td>ITRA, NPART, TTRAF, TWTRA, TWDTRA, TSTRA, TSDRA</td>
</tr>
<tr>
<td>15. 24. 20. 9. 22. 20.</td>
<td>XPART(NPART,1)</td>
</tr>
<tr>
<td>25. 30. 36. 28. 23. 16.</td>
<td>XPART(NPART,2)</td>
</tr>
<tr>
<td>4. 4. 4. 4. 4. 4.</td>
<td>XPART(NPART,3)</td>
</tr>
<tr>
<td>3 14 15 16</td>
<td>TIJMAX, TIJ(J,1)</td>
</tr>
</tbody>
</table>
Appendix D

TEMPOL:

READ (40,*) ABG
READ (40,*) XBG(I), YBG(I), TBG(I), ZSBG(I)
10 CONTINUE

READ (40,*) GAMT, ZINP

READ (40,*) ATG, IFTG
DO 11 I=1,ATG
READ (40,*) NTG(I), XTG(I), YTG(I), ZSTG(I)
DO 11 J=1,NTG(I)
READ (40,*) TTG(J,I), ZTG(J,I)
11 CONTINUE

VELPOL:

READ (40,*) AMG
DO 10 I=1,AMG
READ (40,*) XMG(I), YMG(I), UMG(I), VMG(I), ZMG(I)
10 CONTINUE

READ (40,*) ASG, IFSG
DO 20 I=1,ASG
READ (40,*) NSG(I), XSG(I), YSG(I), ZSSG(I)
DO 20 J=1,NSG(I)
READ (40,*) USG(J,I), VSG(J,I), ZTG(J,I)
<table>
<thead>
<tr>
<th>Variable</th>
<th>Type / Dimension</th>
<th>Unit</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABG</td>
<td>Integer / 1</td>
<td>-</td>
<td>Number of temperature measuring stations on the surface &gt; 0: absolute temperature as input &lt; 0: potential temp. as input</td>
</tr>
<tr>
<td>XBG, YBG</td>
<td>Real / ABG</td>
<td>m</td>
<td>Distance between origin and surface temperature measuring, x/y-direction</td>
</tr>
<tr>
<td>TBG</td>
<td>Real / ABG</td>
<td>C</td>
<td>Air temperature at the surface</td>
</tr>
<tr>
<td>ZSBG</td>
<td>Real / ABG</td>
<td>m</td>
<td>Surface height at measuring location</td>
</tr>
<tr>
<td>GAMT</td>
<td>Real / 1</td>
<td>C/m</td>
<td>Constant temperature gradient in the upper air</td>
</tr>
<tr>
<td>ZINP</td>
<td>Real / 1</td>
<td>m</td>
<td>Height (ASL) where temperature starts to become only dependant of z-coordinate</td>
</tr>
<tr>
<td>ATG</td>
<td>Integer / 1</td>
<td>1</td>
<td>Number of upper air sounding locations &gt; 0: absolute temperature as input &lt; 0: potential temp. as input (in Celsius both)</td>
</tr>
<tr>
<td>IFTG</td>
<td>Integer / 1</td>
<td>1</td>
<td>= 0: ZTG is height above sea level = 1: ZTG is height above surface</td>
</tr>
<tr>
<td>NTG</td>
<td>Integer / ATG</td>
<td>1</td>
<td>Number of temperature soundings for a certain location</td>
</tr>
<tr>
<td>XTG, YTG</td>
<td>Real / ATG</td>
<td>m</td>
<td>Distance between origin and upper air temperature sounding location, x/y-direction</td>
</tr>
<tr>
<td>ZSTG</td>
<td>Real / ATG</td>
<td>m</td>
<td>Surface height at upper air temperature sounding location</td>
</tr>
<tr>
<td>TTG</td>
<td>Real / ATG,NTG</td>
<td>C</td>
<td>Sounded temperature</td>
</tr>
<tr>
<td>ZTG</td>
<td>Real / ATG,NTG</td>
<td>m</td>
<td>Height of temperature sounding</td>
</tr>
<tr>
<td>AMG</td>
<td>Integer / 1</td>
<td>-</td>
<td>Number of wind measuring stations at the surface</td>
</tr>
<tr>
<td>XMG, YMG</td>
<td>Real / AMG</td>
<td>m</td>
<td>Distance between origin and surface wind measuring, x/y-direction</td>
</tr>
<tr>
<td>UMG, VMG</td>
<td>Real / AMG</td>
<td>m/s</td>
<td>Wind component of surface measuring x/y-direction</td>
</tr>
<tr>
<td>ZMG</td>
<td>Real / AMG</td>
<td>m</td>
<td>Height of wind measuring station</td>
</tr>
<tr>
<td>ASG</td>
<td>Integer / 1</td>
<td>-</td>
<td>Number of upper air wind soundings</td>
</tr>
<tr>
<td>VARIABLE NAME</td>
<td>DESCRIPTION</td>
<td></td>
<td></td>
</tr>
<tr>
<td>---------------</td>
<td>-------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>ABG</strong></td>
<td>Inputs for boundary conditions</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>XBG</strong></td>
<td>X coordinate of boundary point</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>YBG</strong></td>
<td>Y coordinate of boundary point</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>TBG</strong></td>
<td>Time before the boundary condition</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>ZSBG</strong></td>
<td>Height of boundary condition</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>GAMT</strong></td>
<td>Ambient mean temperature</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>ZINP</strong></td>
<td>Ambient mean potential temperature</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>ATG</strong></td>
<td>Ambient temperature</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>IFTG</strong></td>
<td>Ambient temperature definition</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>NSG</strong></td>
<td>Number of wind soundings at a certain location</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>XSG</strong></td>
<td>Distance between origin and upper air wind sounding location, x-direction</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>YSG</strong></td>
<td>Distance between origin and upper air wind sounding location, y-direction</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>ZSSG</strong></td>
<td>Surface height at upper air wind sounding location</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>USG</strong></td>
<td>Sounded wind component, x-direction</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>VSG</strong></td>
<td>Sounded wind component, y-direction</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>ZSG</strong></td>
<td>Height of wind sounding</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>CKEY</strong></td>
<td>Key word</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>LTIME</strong></td>
<td>Time since simulation start</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Appendix E**

The following part is required for time depending boundary conditions only

```
100  CKEY
```

The following part is required for time depending boundary conditions only

```
ATHEN  CKEY
100  LTIME
```
In the beginning of each run the following data is read from unit luvw:

```fortran
READ(LUVW,*) COM1
READ(LUVW,*) COM2
READ(LUVW, '(6I3,2F10.1)') N1,N2,N3,IM2,JM2,KM2, DELX, DELY
READ(LUVW,'(20I4)') (ZE(K),K=0,KM1)
READ(LUVW,'(20I4)') ((IAUX(I,J),I=1,IM1),J=1,JM1)
DO 100 J=1,JM
DO 100 I=1,IM
   ZS(I,J)=REAL(IAUX(I+ISTART,J+JSTART))
100   CONTINUE
```

<table>
<thead>
<tr>
<th>Variable</th>
<th>Type / Dimension</th>
<th>Unit</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>COM1/ COM2</td>
<td>Character*60 / 1</td>
<td>-</td>
<td>Comment card</td>
</tr>
<tr>
<td>N1/ N2/ N3</td>
<td>Integer / 1</td>
<td>-</td>
<td>N1: Number of vector arrays following below N2: Number of scalar arrays following below N3: Number of mixed arrays following below</td>
</tr>
<tr>
<td>IM2/</td>
<td>Integer / 1</td>
<td>-</td>
<td>number of grid points in x/y/z-direction (without boundary points)</td>
</tr>
<tr>
<td>--------</td>
<td>-------------</td>
<td>---</td>
<td>-------------------------------------------------</td>
</tr>
<tr>
<td>JM2/</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>KM2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DELX/</td>
<td>Real / 1</td>
<td>m</td>
<td>gridspacing in x/y-direction</td>
</tr>
<tr>
<td>DELY</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ZE</td>
<td>Integer / 0:KM1</td>
<td>m</td>
<td>vertical grid spacing in meters (terrain influenced)</td>
</tr>
<tr>
<td>IAUX</td>
<td>Integer / IM1,JM1</td>
<td>-</td>
<td>used for storage economy</td>
</tr>
<tr>
<td>ZS</td>
<td>Real / IM, JM</td>
<td>m</td>
<td>Height above sea-level at each grid location (i,j)</td>
</tr>
</tbody>
</table>

The following part is repeated for each new update time:

```
READ(LUVW,240,END=9999) DAT2,TIM2,TIKI,TIM1
READ(DAT2(1:2),'(I2.2)')IDAY
READ(DAT2(4:5),'(I2.2)')IMONTH
READ(TIM2(1:2),'(I2.2)')ISTD
READ(TIM2(3:4),'(I2.2)')IMIN
READ(LUVW,210) HP1
READ(LUVW,210) HP2
DO 1101 K=1,KM1
   READ(LUVW,250) FAK,DELTA,FMIN,FMAX
   READ(LUVW,230) ((IAUX(I,J),I=0,IM1),J=1,JM1)
   DO 1100 J=1,JM
      DO 1100 I=0,IM
         U(I,J,K) = FAK * (REAL(IAUX(I+ISTART,J+JSTART)) - DELTA)
      1100 CONTINUE
   1101 CONTINUE
CONTINUE
DO 1103 K=1,KM1
   READ(LUVW,250) FAK,DELTA,FMIN,FMAX
   READ(LUVW,230) ((IAUX(I,J),I=1,IM1),J=0,JM1)
   DO 1102 J=0,JM
      DO 1102 I=1,IM
         V(I,J,K) = FAK * (REAL(IAUX(I+ISTART,J+JSTART)) - DELTA)
      1102 CONTINUE
   1103 CONTINUE
```

READ(LUVW,210) HP1
READ(LUVW,210) HP2
DO 2101 K=1,KM1
READ(LUVW,250) FAK,DELTA,FMIN,FMAX
READ(LUVW,230) ((IAUX(I,J),I=1,IM1 ),J=1,JM1 )
DO 2100 J=1,JM
   DO 2100 I=1,IM
      W(I,J,K) = FAK * (REAL(IAUX(I+ISTART,J+JSTART)) - DELTA) + 1.E-10
   2100  CONTINUE
2101  CONTINUE
READ(LUVW,210) HP1
READ(LUVW,210) HP2
DO 2201 K=0,KM1+1
   READ(LUVW,250) FAK,DELTA,FMIN,FMAX
   READ(LUVW,230) ((IAUX(I,J),I=1,IM1 ),J=1,JM1 )
   DO 2211 J=1,JM
      T(I,J,K) = FAK * (REAL(IAUX(I+ISTART,J+JSTART)) - DELTA) + 1.E-10
   2211  CONTINUE
2201  CONTINUE
READ(LUVW,210) HP1
READ(LUVW,210) HP2
DO 2301 K=0,KM1+1
   READ(LUVW,250) FAK,DELTA,FMIN,FMAX
   READ(LUVW,230) ((IAUX(I,J),I=1,IM1 ),J=1,JM1 )
   DO 2300 J=1,JM
      KT(I,J,K) = FAK * (REAL(IAUX(I+ISTART,J+JSTART)) - DELTA) + 1.E-10
   2300  CONTINUE
2301  CONTINUE
READ(LUVW,210) HP1
READ(LUVW,210) HP2
DO 2401 K=0,KM1+1
   READ(LUVW,250) FAK,DELTA,FMIN,FMAX
   READ(LUVW,230) ((IAUX(I,J),I=1,IM1 ),J=1,JM1 )
   DO 2400 J=1,JM
      KE(I,J,K) = FAK * (REAL(IAUX(I+ISTART,J+JSTART)) - DELTA) + 1.E-10
   2400  CONTINUE
2401  CONTINUE
DO 3000 JJJ=1,N3
   READ(LUVW,'(I4)') KG
   DO 3333 K=1,KG
      READ(LUVW,'(I2,I4)') KMODE(K),ZEG(K)
READ(LUVW,210) (HP3(I,K),I=1,15)
READ(LUVW,250) FAK,DELTA,FMIN,FMAX
READ(LUVW,230) ((IAUX(I,J),I=1,IM1 ),J=1,JM1 )
DO 3102 J=1,JM
DO 3102 I=1,IM
MIX(I,J,K) = FAK * (REAL(IAUX(I+ISTART,J+JSTART)) - DELTA) + 1.E-10
            CONTINUE
3102    CONTINUE
3333    CONTINUE
3000 CONTINUE

<table>
<thead>
<tr>
<th>Variable</th>
<th>Type / Dimension</th>
<th>Unit</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>DAT2/</td>
<td>Character*60 / 1</td>
<td>-</td>
<td>Simulation Date and Hour</td>
</tr>
<tr>
<td>TIM2/</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TIKI/</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TIM1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IDAY/</td>
<td>Integer / 1</td>
<td></td>
<td>Simulation Day, Hour, Minute</td>
</tr>
<tr>
<td>ISTD/</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IDAY/</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IMIN</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HP1/</td>
<td>Character /</td>
<td></td>
<td>Comment cards</td>
</tr>
<tr>
<td>HP2/</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HP3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FAK/</td>
<td>Real / 1</td>
<td>m</td>
<td>scaling factor</td>
</tr>
<tr>
<td>DELTA/</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FMIN/</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FMAX</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IAUX</td>
<td>Integer / IM1,JM1</td>
<td></td>
<td>(in compressed form) fak*iaux+delta yields actual value</td>
</tr>
<tr>
<td>U</td>
<td>Real / 0:IM+1,0:JM+1,0:KM+1</td>
<td>m/s</td>
<td>Horizontal Wind Velocity</td>
</tr>
<tr>
<td>V</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>W</td>
<td>Real / 0:IM+1,0:JM+1,0:KM+1</td>
<td>m/s</td>
<td>Vertical Wind Velocity (not used)</td>
</tr>
<tr>
<td>T</td>
<td>Real / 0:IM+1,0:JM+1,0:KM+1</td>
<td>K</td>
<td>Potential Temperature</td>
</tr>
</tbody>
</table>
Appendix A-2

The FORTRAN statements to read the emissions inventory are given below. The meaning of the variables are explained in the consecutive table.

```
READ(LEMI,'(A60)') TITLE1
READ(LEMI,'(A60)') TITLE2
READ(LEMI,'(2I3,4F10.1,2I3)') IMG,JMG,DXG,DYG,XG,YG,NSPE,NZC
READ(LEMI,'(10(F7.1))') ( ZC(NN,1),NN=2,NZC +1 )
READ(LEMI,'(10(F7.1))') ( ZC(NN,2),NN=2,NZC )
DO 20 NN=1,NSPE
   READ(LEMI,'(I3,A6,A40)') ISPE0(NN),CSPES(NN),CSPEL
20 CONTINUE
READ(LEMI,'(4X,F7.2)',END=9999) TIME
READ(LEMI,'(7E10.5)') (FAKEQ(ISPE0(IN)),IN=1,NSPE)
1000 READ(LEMI,CFORM) IG, JG, IZC, NSP, (ISPE(NN),IEQ(NN), NN=1,NSP)
9999 CONTINUE
```

<table>
<thead>
<tr>
<th>Variable</th>
<th>Type / Dimension</th>
<th>Unit</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>TITLE1</td>
<td>Character*60 / 1</td>
<td>-</td>
<td>Comment card</td>
</tr>
<tr>
<td>TITLE2</td>
<td>Character*60 / 1</td>
<td>-</td>
<td>Comment card (if Position 1-6 contains 'FORMAT', a user-defined Format can be specified to read IG, JG, IZC, NSP, (ISPE(NN),IEQ(NN), NN=1,NSP) )</td>
</tr>
<tr>
<td>IMG</td>
<td>Integer / 1</td>
<td>-</td>
<td>Number of grid points in x/y-direction used in the emissions inventory</td>
</tr>
<tr>
<td>JMG</td>
<td>Integer / 1</td>
<td>-</td>
<td>Number of grid points in x/y-direction used in the emissions inventory</td>
</tr>
<tr>
<td>Variable</td>
<td>Type</td>
<td>Description</td>
<td></td>
</tr>
<tr>
<td>----------</td>
<td>------</td>
<td>-------------</td>
<td></td>
</tr>
<tr>
<td>DXG, DYG</td>
<td>Real / 1 m</td>
<td>(Constant) horizontal grid spacing in the emissions inventory</td>
<td></td>
</tr>
<tr>
<td>XG, YG</td>
<td>Real / 1 m</td>
<td>Origin of emissions inventory relative to the computational domain of MEMO</td>
<td></td>
</tr>
<tr>
<td>NSPE</td>
<td>Integer / 1</td>
<td>Number species given in the emissions inventory</td>
<td></td>
</tr>
<tr>
<td>NZC</td>
<td>Integer / 1</td>
<td>Number of height levels in the emissions inventory</td>
<td></td>
</tr>
<tr>
<td>ZC</td>
<td>Real / NZC,2 m</td>
<td>Lower (1) and upper (2) boundary of a height level where emissions are specified in the emissions inventory</td>
<td></td>
</tr>
<tr>
<td>ISPE0</td>
<td>Integer / NSPE</td>
<td>Identifier of each species</td>
<td></td>
</tr>
<tr>
<td>CSPES</td>
<td>Character*6 / NSPE</td>
<td>Unit where the species is given</td>
<td></td>
</tr>
<tr>
<td>CSPEL</td>
<td>Character*40 / 1</td>
<td>Name of the species</td>
<td></td>
</tr>
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</table>

The following part is repeated for each new update time

<table>
<thead>
<tr>
<th>Variable</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>FAKEQ</td>
<td>Real / NSPE</td>
<td>Scaling factor of the species (can be different for each new update time)</td>
</tr>
<tr>
<td>IG, JG, NZC</td>
<td>Integer / 1</td>
<td>Horizontal and vertical grid index where species are given</td>
</tr>
<tr>
<td>NSP</td>
<td>Integer / 1</td>
<td>Number of species given for this specific location (a closing record has to be specified with NSP=0 at the end of each update time)</td>
</tr>
<tr>
<td>ISPE</td>
<td>Integer / NSP</td>
<td>Identifier of each species (according to ISPE0)</td>
</tr>
<tr>
<td>IEQ</td>
<td>Integer / NSP</td>
<td>Emission of species ISPE (in compressed form) IEQ*FAEQ must be in [Kg / h]</td>
</tr>
</tbody>
</table>

### Appendix A-3

**Initial state**

```fortran
IF(IBCEXT.eq.1) THEN
    READ(LBCOUT,*1) KIN,NN
    IF(KIN.eq.0.or.NN.eq.0) GOTO 1000
    READ(LBCOUT,*1) ( ZIN(K), K=1,KIN)
    DO NS=1,NN
        READ(LBCOUT,'(I3,7E11.4)') ISPECI(NS),( YZINIT(K,ISPECI(NS)), K=1,KIN)
    ENDDO
1000     CONTINUE
ENDIF
```

END
Boundary conditions
IF(IBCEXT.eq.1) THEN
  READ(LBCOUT,*) KBC,NN
  IF(KBC.eq.0.or.NN.eq.0) GOTO 1000
  READ(LBCOUT,*) (ZBC(K), K=1,KBC)
  DO NS=1,NN
    READ(LBCOUT,'(I3,7E11.4)') ISPECI(NS),(YBC,ISPECI(NS), K=1,KBC)
  ENDDO
2000 CONTINUE
ENDIF
ENDF

External boundary conditions
1 READ(LBCOUT,'(E11.4,8I3)')TPRINT,IML,IMH,JML,JMH,KML,KMH,NN
  READ(LBCOUT,'(25I3)') (ISPECI(NS), NS=1,NN)
  DO 2000 K=KML,KMH
    DO 2000 NS=1,NN
      READ(LBCOUT,'(7E11.4)') (YX(JJ,K,ISPECI(NS),1), JJ=JML,JMH)
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Integrated System for Intelligent Regional Environmental Monitoring & Management

ISIREMM

COPERNICUS – 2

Contract N ICA2-CT-2000-10024

Contractor : Space Research Institute – P05

REPORT for the First Year

1. Task formulation

Atmospheric pollution modelling in the real-time regime is very actual task. Its solution forms scientific basis for engineering of a system of diagnosis, prognosis and urban air pollution quality control.

In this report there is formed the task of atmospheric pollution modelling, developed the mathematical model and considered its information support. The special attention is paid to the problem of atmospheric monitoring by the methods of acoustic sounding and remote sensing. Below there is given the task formulation as following definite limitations.

Object.
The object under modelling is the urban airshed of the city situated in highlands.

Meteosituation.
Anticyclonic situation to be characterized by high air pollution level is considered.

 Territory.
The urban airshed’s size is defined by local winds such as mountain-valley circulation and thermics around urban “heat island”. In anticyclonic situation they form the wind field. The inversion layer’s base presents the upper boundary of the calculated domain. The horizontal sizes of the calculated domain are equal to ~ 100 km, i.e. cover the city and its sites.

Temporal frames.
The period under calculation covers the time of anticyclonic situation keeping – from 1 to 5 days. The calculated interval not exceeds 1 hour.

Sources.
There are accounting for all main kinds of urban emission sources – vehicle, enterprises with tall stacks, urban services and private houses emitting pollutants into the surface layer.

All mentioned above limitations may vary during adopting the model to the concrete town.

2. Model formulation (WP 04)

Any mathematical model of the atmospheric pollution leans upon conservation laws, which may be presented in the form of differential equations:
\[
\frac{\partial C_i}{\partial t} + \frac{\partial}{\partial x} (C_i u) + \frac{\partial}{\partial y} (C_i v) + \frac{\partial}{\partial z} (C_i w) = \frac{\partial}{\partial x} \left( K_x \frac{\partial C_i}{\partial x} \right) + \\
\frac{\partial}{\partial y} \left( K_y \frac{\partial C_i}{\partial y} \right) + \frac{\partial}{\partial z} \left( K_z \frac{\partial C_i}{\partial z} \right) + Q_i + R_i, \tag{1}
\]

where \( C_i \) is the mass concentration of \( i \)th species; \( u, v, w \) are the airflow velocity components; \( K_x, K_y, K_z \) are the diagonal elements of eddy diffusivity; \( Q_i \) is the intensity of emission of species \( i \); \( R_i \) is the rate of generation of species \( i \) by photochemical reaction.

Concrete definition of the problem involves setting up the initial and boundary conditions, determining coefficients in Equation (1), specifying source terms, etc. This process is the most difficult stage of model construction.

The boundary conditions are being set with regard to special features of the locality wherein the pollutant spreads. At the upper boundary of the computational domain the impermeability condition is assumed:

\[
\frac{\partial C_i}{\partial z} = 0 \text{ at } z=H(t), \tag{2}
\]

that is valid at a height \( H \) of the bottom of the inversion layer.

The lower boundary of the domain is at a level of the roughness length \( z_0 \). Here the material balance is taken into account:

\[
-K_z \frac{\partial C_i}{\partial z} + V_{d_i} C_i = \alpha_i \text{ at } z=z_0, \tag{3}
\]

where \( \alpha_i \) is the abundance of pollutant sources within the surface boundary layer, \( V_{d_i} \) is the velocity of dry deposition to the earth's surface.

At the lateral planes of the domain the permeability condition is set up, because the pollutants are supposed to be carried out without obstruction:

\[
C_i \bigg|_{\Gamma} = 0 \text{ at } V_n < 0 \text{ and } \frac{\partial C_i}{\partial n} \bigg|_{\Gamma} = 0 \text{ at } V_n \geq 0, \tag{4}
\]

where \( \Gamma \) is the lateral surface, \( n \) is the outer normal to \( \Gamma \), \( V_n \) is the normal component of the wind velocity.

The problem is made self-contained by the initial condition, which may be written in the most general form:

\[
C_i(t, x, y, z) = C_i^0(x, y, z) \tag{5}
\]

As evident from the general formulation of the problem (1)-(5), its numerical solution requires a huge volume of information: three-dimensional wind fields represented by the velocities \( u, v, \) and \( w \); the eddy diffusivities, \( K_x, K_y, \) and \( K_z \); the source terms, \( Q_i \) and \( R_i \), and the dynamics of the upper boundary of the computational domain.

Such volume of detailed information is almost impossible to obtain in actual practice. This is why the general formulation of the problem has to be simplified. The main idea is that Equation (1) is
subject to averaging over the vertical axis taking into account the boundary conditions at \( z=z_0 \) and \( z=H(t) \):

\[
\overline{f} = \frac{1}{H-z_0^H} \int_{z_0^H} f \, dz.
\]  
(6)

The following assumptions have been used at averaging:

the wind velocity and the pollutant concentration are distributed along the vertical axis in this fashion:

\[
V = a_v(x,y) + b_v(x,y) \lambda(z)
\]

\[
C = a_c(x,y) + b_c(x,y) \mu(z)
\]

where the functions \( a_v, b_v, a_c, b_c, \lambda, \) and \( \mu \) are determined on evidence derived from direct observations and in view of the balance at the surface. The analytical form of \( \lambda(z) \) and \( \mu(z) \) for the urban conditions is given by power or logarithmic dependence with the usage of acoustic sounding data;

the dynamics of the inversion layer's lower boundary adheres to the free surface equation:

\[
\frac{\partial H}{\partial t} + u_H \frac{\partial H}{\partial x} + v_H \frac{\partial H}{\partial y} - w_H = 0;
\]

\[K_x = K_y = K = \text{const};\]

only inert pollutant is considered, i.e. \( R=0 \).

As a result, Equations (1)-(5) are transformed into the two-dimensional ones of the following form (index \( i \) is omitted):

\[
\frac{\partial C}{\partial t} + \frac{1}{H-z_0} \frac{\partial H}{\partial t} C + \frac{\partial H}{\partial x} (C u) + \frac{\partial H}{\partial y} (C v) = - \frac{\partial}{\partial x} \left[ b_v b_c \cos \beta (\lambda \mu - \bar{\lambda} \bar{\mu}) \right] - \frac{\partial}{\partial y} \left[ b_v b_c \sin \beta (\lambda \mu - \bar{\lambda} \bar{\mu}) \right] +
\]

\[
K \frac{\partial^2 C}{\partial x^2} + K \frac{\partial^2 C}{\partial y^2} + \frac{\alpha}{H-z_0} \left[ 1 - \frac{V_d (\bar{\mu} - \mu_0)}{K_z \mu_0 + V_d (\bar{\mu} - \mu_0)} \right] - \frac{V_d}{H-z_0} \frac{K_z \mu_0}{K_z \mu_0 + V_d (\bar{\mu} - \mu_0)} \overline{C} + \overline{Q}
\]

\[
C|_{t=0} = 0 \quad \text{at} \quad V_m < 0
\]

\[
C(0,x,y) = C^0(x,y) \quad \text{at} \quad t = 0
\]
3. Information support (WP 01, WP 02)

The above given model formulation is simple enough and this factor lays in strong requirements to information support. On the scheme in Fig. 1 there is shown the structure of information support to be realized in the ISIREMM project. AS seen from Fig. 1 three types of monitoring data will be used in the model.

The data of acoustic sounding provide vertical profile of the wind and inversion layer dynamics. In the next section the system for acoustic sounding being created at present time in the frameworks of the project is described.

The block for meteorological data receiving is supposed to be available. But realization of such block in on-line regime is not foreseen in the frameworks of this project.

Remote sensing data are necessary for creating of current land-use maps and estimation, on the base of these maps, of ground surface parameters (Z_0, V_d).

4. Acoustic sounding (WP 03, WP 05)

There are being carried out the works on upgrade of sodar complex.

Upgrade consists in two types of activities:

1. Antenna complex mounting on the grown suitable for measurements conducting;
2. Upgrade of electronic components i.e. transposition on new element base in receiving block.

The antenna mounting included installation of three antennae for sending of acoustic signal and receiving reflected one from atmospheric heterogeneities.

To define wind direction estimation of parameters of the reflected signal in reciprocally perpendicular directions should be accounted for. So, two antennae have been placed in such a way that their horizontal rotating axes allow to direct one of them to north or south, the second – to east or west. And moreover the construction of their propers gives the possibility to direct them (the antennae) on 30° from vertical line. The third antenna is intended for estimation of vertical wind velocity and for this reason it is directed along vertical line.

The scheme of the antennae disposition has been chosen in accordance with the requirements of their disposition (Fig. 2).

For stable arranging of the antenna concrete square grounds (700*700*200 mm) were poured over the propers were placed in them.

The works on electroboards and the block for heating of antennae in winter season have been done.

Some moments of mounting works are shown on photo in Fig. 3,4.

The second stage of works is connected with modernization of the system for sodar data processing in real time mode.

To make operative control for atmosphere and prognosis of air parcels moving it is necessary to process the acoustic sounding data immediately during measurements carrying out. To provide such regime the cycle of the reflected signal passing from the measuring block’s input chains to display (or printer) should be fulfilled earlier than that of acoustic signal passing from emanator to sounding upper point and returning to the receiver. In the “LATAN-3” acoustic locator sounding begins from 30 m and thereby the time of initial signal receiving is equal to ~ 0.1 sec.

During this time, in the technological chain from antenna intensifier to display the following processes should be done:

1. preliminary intensifying of reflected signal;
2. transmitting of intensified signal from antenna intensifier to the measuring block through the cable;

3. preliminary processing of acoustic signal in the measuring block:
   a) wide strip filtration of an input signal in the frequency band: 1800 Hz - 2200 Hz;
   b) compensation of spherical divergence of the sound ray;
   c) narrow strip filtration of noise in frequency of 1975 Hz and 2000 Hz;
   d) measuring of frequency and registration of S/N (ratio signal/noise is lesser than normal one) signal;
   e) forming of meander and TTL-levels conciliation;

4. transmitting of RS-232 data through consequent channel;

5. coding of measured digital data into graphical image on the display of PC.

Duration of these stages depends on rapidity of including equipment and quantity of transporting steps. Rapidness of transformations also depends on operative memory volume, speed of changing with hard memory.

The system of acoustic air sounding developed earlier was able to solve the following tasks:

1. Receiving and pre-processing of data by control computer;

2. Recording the data on the network disk with concurrent distribution throughout the hierarchical structure of directories and sub-directories according to year, month, day and hour of measurements;

3. Creating the data archive on EXEBYTE magnetic tapes.

The accessibility of remote sensing data to all network users was thereby attained.

One of the principal problems currently under study is exporting acoustic sounding data to the GIS in the real-time mode. With this in mind, a proper structure of the database has been designed and implemented to meet exacting requirements of preparation procedure dealing with data used in contaminant transport model.

At this stage the following works have been performed:

- The structure of an open database has been created;
- A channel capable of real-time transmitting huge amounts of information to the GIS has been thoroughly tested;
- The algorithms corresponding to different time intervals (from 1 to 10 min) have been developed and realized;
- A graphic user interface in the form of a window depicting vertical wind profile has been developed.

Fig. 5 presents an external view of the window of the graphic interface where the vertical wind profile of lower 500-meter layer of the atmosphere of Almaty is shown. Each of the sections provides a wind vector in polar coordinates.

The above data are of December 11, 1996 and are characteristic of the conditions of winter anticyclonic period. The diagram clearly shows that there is no sensible wind within the height of 270 m. It appears and sharply increases within the inversion layer. These results are in excellent agreement with the well-known facts of contaminant accumulation within the sub-inversion layer.

The user interface permits:

- To scroll a sequence of diagrams like that depicted in Fig. 5;
• To modify scale and spacing of the sections;
• To perform averaging procedure over time and/or vertical coordinate.

5. Remote sensing (WP 02)

There exist several ways to estimate surface roughness and dry deposition velocity. The first one supposes the analysis of passive sensing data i.e. reflecting capability of ground surface. Namely, these free data are collected from AVHRR/NOAA and TERRA/MODIS. Since Almaty is green town the surface roughness and dry deposition velocity in summer season may be calculated with the usage of empirical formulae in dependence on NDVI and LAI. For example, J.S.Pillai and others [Asian-Pacific Remote Sensing and GIS Journal, v. 13, December 2000, pp. 51-54] estimate the rural surface roughness as follows:

\[ Z_0 = \exp(-5.5 + 5.8 \text{NDVI}) \]  \hfill (10)

where

\[ \text{NDVI} = 0.5 \text{NDVI of chilli} + 0.3 \text{NDVI of wheat} + \\
\quad + 0.2 \text{NDVI of soil} + 0.1 \text{NDVI of potato} \]  \hfill (11)

It should be noted that \( Z_0 \) and \( V_d \) are not very strongly variable. Probably, in the period from spring to autumn building of 4-5 land-use maps will be sufficient.

To build land cover maps there have been processed the images of Tomsk and its environs. The images were received from the RESOURCE-01 N 3 satellite on July, 4, 2000 (MSU-E scanner) and on May, 5, 2000 (MSU-SK scanner). Image processing was made by ERDAS Imagine software. The images were processed in 2 stages: primary processing and thematic classification.

Primary processing included geocoding, filtration and brightness normalization (Fig. 6).

Classification consisted in transformation with the usage of Supervised Classification. The image from MSU-SK scanner (35 m resolution) has been used as an input file. To create the input Signature File there has been applied the ground cartographic information (1:1 000 000) given by the colleagues from Tomsk. The information contains the following coverages:

• hydrographic objects (lakes, rivers, watersheds, channels);
• populated areas (towns, settlements);
• railways, highways, roads etc.;
• vegetation (forests).

Possessing these cartographic data we could identify water objects, large populated areas, forests, vegetation (Fig. 7).

But for more precise identification of vegetation, forests, agricultural lands, desert territories more detailed maps on large scales should be available.

At present time the work on image identification and analysis is being continued.
Z₀, V_d
Roughness and dry deposition velocity to ground surface

λ(z), µ(z)
Vertical profiles of wind and concentration

u(x,y,t), v(x,y,t)
Wind field

Kₓ, Kᵧ, Kz
Turbulent diffusivities

Q(x,y,z,t), α(x,y,t)
Elevated and ground emissions

H(t)
Inversion layer dynamics

Mathematical model

The "Urban Air Pollution" GIS

MONITORING

ACOUSTIC SOUNDING

METEOROLOGICAL DATA

REMOTE SENSING
Fig. 2. The scheme of acoustic antennae disposition
Fig. 3. Acoustic locator mounting
Fig. 4. Acoustic locator mounting
Acoustic Locator

Fig. 5 Vertical profile of wind vector in atmosphere of Almaty city
Fig. 6. Image of Tomsk after primary processing
Fig. 7. Image of Tomsk after thematic classification
1. Introduction

The main objective of the scientific group of the Institute of Physics, NASB (P06) is to design the methodology for lidar measurements to apply it in the ISIREMM system. The Working Program comprises the optimisation of the measurement procedure and algorithms for lidar data processing to efficiently use lidars as ISIREMM remote sensors of atmospheric conditions. Field investigations are envisaged to refine methodological recommendations and software.

According to the Working Plan, group P06 performed studies within the frame of tasks WP1 - WP5, WP07 during the first executive year.

2. Selection of objects for lidar monitoring and analysis of requirements to lidar data (within the frame of WP 01, Requirements analysis and data compilation)

The main reason for incorporating lidar sensors into the environmental monitoring system is their unique ability to represent operative information on 3D distributions of polluting aerosol and gas atmospheric species and to provide remote observations of pollutant transfer over an industrial site. The below tasks of lidar monitoring supported by procedures, being under development by the Institute of Physics P06 have been elaborated and agreed with the Leading Executing Institution P02 of the task WP03 on the base of the evaluation of the requirements to information provisions of the ISIREMM system and facilities of modern lidar systems:

2.1. Estimating the emission power of local and distributed polluting sources.

The objective of lidar measurements is to determine the emission power of local jet-kind sources and distributed sources of rock-dump or highway kind. It is supposed to use lidar technology to independently estimate power of polluting emissions in a region to correct data of industrial services.

2.2. Validating the simulations of pollutant transfer.

A problem is posed to design the procedure for comprehensive investigations of spatial pollutant distributions by utilizing lidars and other sensors to compare experimental data with mathematical simulations of pollutant transfer.

2.3. Refining the procedure of lidar monitoring of air pollution over an industrial center.

The objectives of this task are to acquire the experience for routine lidar monitoring of air pollution in an industrial center, to upgrade the equipment and monitoring procedure, and to choose the format of data presentation. Lidar monitoring data on the dynamics of pollutant distributions in the atmosphere will be used to construct models of pollutant transfer. Operative lidar information is
needed to detect dangerous emissions under emergency situations.

The design of procedures for lidar monitoring and their implementation in the ISIREMM system are made within the scope of the following Project tasks:

- designing the procedures for lidar monitoring and the algorithms for data processing, WP04, WP05;
- upgrading the equipment complex, WP03;
- designing the software structure and format of data presentation, WP02;
- mathematical simulation of pollutant transfer under field lidar experiments, WP07;
- field tests of the designed procedures, experimental checking of the simulation results, WP04, WP05, WP08, and WP09;
- adapting the structure of the archive of lidar data files, WP06.

3. Design of software for lidar data processing (within the scope of WP02, Software adaptation and implementation)

There is designed a computer package to provide lidar data processing while measuring according to items 2.1 to 2.3. The package is designated to process information starting from observations up to data transfer to a user. It includes the following:

- programs to control the lidar system while measuring;
- programs to retrieve distributions of atmospheric aerosol and gas components along a sounding path by lidar data;
- database of lidar sounding;
- program package to map pollutant fields.

The control programs are adapted to the specifications of the lidar systems used to monitor pollutants. With this, the unique format of output data files is conserved. The body of a single measurement file is about 8.5 K. The body of lidar data for a single measurement series according to items 2.1 to 2.3 is 200 to 500 K.

Aerosol parameters are measured by the multi-frequency sounding method. The respective program implements the algorithm for solving a set of lidar equations by the optimal linear estimation method to close the set. Concentrations of gaseous species are measured by the differential absorption lidar method while sounding at two wavelengths on and off the absorption band of a species studied.

The lidar database is formed by the package ACCESS.

Digital pollutant maps superimposed on a city electron map are constructed to visualize the data. The information on the structure of lidar data files has been transferred to the Executor P02.

4. Refining the lidar complex (within the scope of WP03, Remote sensor development)

To refine the procedures for lidar monitoring, there are equipped two following lidar systems:

- Multi-purpose mobile lidar station MLS (Fig. 1) is designated to measure concentrations of aerosol species and polluting gaseous components near industrial enterprises. Aerosols are sounded in the visible. Concentrations of polluting gases are measured by the differential absorption lidar method over the mid-IR by using a tuneable TEA CO2-laser. The lidar is mounted in a car van. The closed section of the van contains a control PC and a multi-channel recording system.
- Omnidirectional (panoramic surveying) lidar station (Fig.2) is created to refine methods for lidar monitoring of atmospheric pollutants over the scale of an industrial center, for mapping of spatial pollutant fields, and detection of polluting emissive sources.

The omnidirectional station includes two lidars. Their specifications are close to the aerosol and gas channels of the MLS. A lidar site for panoramic surveying is equipped on the building of the Institute of Physics, where routine lidar observations of polluting impurities of the city air basin are made.

Table 1 shows the specifications of the lidar equipment.

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<th>Lidar type</th>
<th>Mobile lidar station</th>
<th>Panoramic surveying lidar station</th>
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<td>Iris channel</td>
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5. Design of procedures for lidar monitoring and algorithms for data processing (within the frame of WP05, Monitoring data integration and WP04, Baseline simulations)

During the first year of the Project execution, the investigations have been carried out to design lidar procedures for estimating power values of pollutant emissions and validating mathematical models of pollutant propagation.

5.1. Estimating the power of emissive sources by lidar sounding data.

The procedure to compute power values of polluting emissions is based on lidar measurements of concentration distributions of a polluting impurity at a surface surrounding the polluting source and
on calculations of the impurity flux difference at the surface. With this, the wind velocity field is measured or simulated. Fig. 3 shows the experimental scheme approved under field conditions of determining the power of aerosol emissions at a potassium enterprise of Soligorsk (Belarus). We have carried out the investigation of the spatial distributions of dust mass concentrations over a horizontal and vertical planes in the atmosphere above the enterprise. Different degree of blackness in Fig. 3 illustrate particle concentrations. An arrow indicates the wind direction. The layout of the enterprise with a processing mill and waste piles of exhaust rock (ER) is shown too. Curves 1 to 6 in Fig. 3 are the projections of the vertical planes where the dust concentrations have been observed. Incorporating the data on wind velocity measurements into consideration, we have estimated the dust fluxes through the sections and power of the emissions. We made these evaluations for the enterprise as a whole and for separate sources at its territory. The derived results have been compared with estimations of the emission power calculated with regard to the loading of technological equipment. The both results agree satisfactorily.

Errors in power estimations depend on measurement accuracy of concentration distributions over the jet section. Sounding schemes were designed to determine optimal observational conditions.

5.1.1. Estimating the errors in lidar-measured power of dust emissions

The method to derive power of a stationary source of an impurity includes the measurements of the integral of the concentration along an arbitrary jet section to subsequently multiply it by wind velocity. The resulting impurity flux is the source power. However, a real transient character of the turbulent wind velocity field and resulting transient concentration distributions in the jet as well as finite duration of lidar observations give rise to errors in measured emission power values. A jet from a smoke stack at moderate distances from the stack can be considered as a current of a passive impurity with transverse sizes that are much smaller than the external scale of the wind turbulence. The jet shifts randomly for a time between laser pulses, and the measured integral appears as a random quantity. The objective of this task is to estimate the accuracy of the said method for measuring dust emissions with regard to the features of lidar observations.

According to a jet model by Gifford1, the jet axis bends smoothly to constantly change its position by arbitrary means and the cross distribution of concentration is assumed to be a stationary one approximated by a Gaussian function. The normal law approximates the probability density of jet axis deflection from its mean position.

For simplicity, we will believe that one makes observations from one side in the vertical plane in the direction normal to the mean wind velocity. In this case, it is important to regard vertical movements of the jet. Estimations show that vertical shifts of the jet can by several times exceed its width. Experiments are usually arranged so that a laser operating with pulse repetition rate \( \nu \) Hz transmits \( N \) averaging pulses along a single sounding path, then after duration \( T \), required to change the observation direction, one starts measurements along another path. The interval of the observation directions should exceed the angular size of the probable jet location.

The averaging over the jet axis location gives mean quantity \( \bar{I} \) that is proportional to the integral of the concentration over the jet cross-section and the mean value of the said quantity squared.

\[
\langle \bar{I} \rangle = \sum_{r=1}^{K} \frac{Q}{2\pi (S^2 + M^2)} \exp \left\{ -\frac{z_k^2}{2(S^2 + M^2)} \right\}, \quad (5.1.1)
\]
\[ \mathcal{T}^2 = \sum_{j=1}^{K} \sum_{k=1}^{K} \sum_{n=1}^{N} \sum_{n'=1}^{N} \frac{1}{N^2} \sqrt{(S^2 + M^2)^2 - M^4 R_{k,k',n,n'}^2} \times \]
\[
\times \exp \left\{ - \frac{z_k^2 + z_{k'}^2 - 2z_kz_{k'}M^2 (S^2 + M^2)^{-1} R_{k,k',n,n'}}{2(S^2 + M^2) - M^4 (S^2 + M^2)^{-1} R_{k,k',n,n'}^2} \right\}, \quad (5.1.2)\]

where \( Q \) is the mean value of the integral of the concentration over the jet cross-section, \( z_k \) is the vertical coordinate of the observation direction, \( S \) is the jet radius, \( K \) is the number of observation directions intersecting the space occupied by the jet.

\[ R_{k,i,n,m} = M^2 R_i^E \left[ U_{k,i} - t_{l,i} \right], \quad (5.1.3) \]

where \( R_i^E (l) \) is the Eulerian normalized velocity correlation function at points separated by distance \( l \), \( M \) is the variance of jet axis displacements, \( U \) is the mean wind velocity.

Figure 4 shows calculated errors \( \varepsilon = \sqrt{\left( \mathcal{T}^2 / \mathcal{I}^2 \right)} - 1 \times 100\% \) while measuring \( I \) value, namely the sum of the signals from each pulse, for weakly stable atmospheric stratification. While computing, the observation coordinates change within interval \( 4\sqrt{2(S^2 + M^2)} \) to approximately twice exceed the zone of possible jet locations.

Specifications of a ruby laser were used for the calculations. Pulse repetition rate is 0.1 Hz, number of averaging pulses is 5 (upper curve) and 20 (lower one), time to rearrange to a new path \( T=10 \) s. Number of sounding paths is 5. One can see that for 20 averaging pulses the error is less than 20% at experiment duration about 17 min.

5.1.2. Procedure to measure power of stationary point gas sources

This paragraph presents an attempt to create a procedure for lidar measurement of gas concentration integral over the jet cross section on the base of the measured integrals of the concentrations along the observation direction, which will not require any spatial resolution along the observation direction. The transient character of a jet owing to large-scale atmospheric turbulence will be taken into account, as for the previous Section, within the scope of the Gifford’s jet model\(^1\).

While sounding along a path with characteristic distance \( h_i \) between the observation direction and simultaneous jet axis, the lidar return is proportional to the following quantity

\[ I_i(h_i) = \int_{-\infty}^{\infty} dx \frac{c_p}{2\pi R^2} \exp \left( \frac{h_i^2 + x^2}{2R^2} \right) \cdot \exp \left\{ -2 \int_{-\infty}^{x} dy \frac{c_p k_p + c_g k_g}{2\pi R^2} \exp \left( - \frac{h_i^2 + y^2}{2R^2} \right) \right\} = \]
\[
= \frac{c_p \beta}{2(c_p k_p + c_g k_g)} \left[ 1 - \exp \left\{ - \frac{2(c_p k_p + c_g k_g)}{\sqrt{2\pi R^2}} \exp \left( - \frac{h_i^2}{2R^2} \right) \right\} \right], \quad (5.1.4)\]
where \( c_p \) and \( c_g \) are, respectively, the aerosol and gas concentration integrals over the cross section, \( k_p \) and \( k_g \) are, respectively, aerosol and gas extinction coefficients per unit aerosol and gas concentration, \( \beta \) is the backscatter aerosol coefficient, \( R \) is the jet radius.

By summing signals from all observation directions or actually integrating across the jet, one obtains the following in the right hand of Eq. (4) after series expansion of the exponent and averaging by jet locations,

\[
S_v = \int T_v(h_i) dh_i = c_p \beta \sum_{n=1}^{\infty} (-1)^{n-1} \left[ \frac{2(c_p k_p + c_g k_g)}{\sqrt{2\pi R^2}} \right]^{n-1} \frac{1}{n! \sqrt{n}}.
\]  

(5.1.5)

The measurements are carried out off the gas absorption band and at the absorption frequency. We believe that the jet is optically thin and the gas makes the main contribution to the absorption at the absorption band.

\[
\frac{c_p k_p}{\sqrt{2\pi R^2}} \ll 1, \quad c_p k_p \ll c_g k_g.
\]  

(5.1.6)

In this case, the signal off the gas absorption band is

\[
S_1 = c_p \beta.
\]  

(5.1.7)

The signal at the absorption band is

\[
S_2 = c_p \beta F \left( \frac{2c_g k_g}{\sqrt{2\pi R^2}} \right),
\]  

(5.1.8)

where

\[
F(x) = \sum_{n=1}^{\infty} (-1)^{n-1} x^{n-1} \frac{1}{n! \sqrt{n}}.
\]  

(5.1.9)

The ratio of the signal difference of Eqs. (7) and (8) to the signal of Eq. (7) is \( 1-F(x) \) that enables one to find doubled optical thickness \( 2c_g k_g / \sqrt{2\pi R^2} \) along the jet diameter and then to derive the concentration integral \( c_g \) over the jet cross section by the known absorption coefficient. Fig. 5 shows the plot of \( 1-F(x) \).

The main problem is the estimation of jet radius \( R \). The upper estimate can be obtained by taking the off signal maximum within observation directions. This direction is obviously to correspond to distance \( h \approx 0 \) between the observation direction and mean location of the jet axis. By averaging
Eq.(4) by jet axis displacements and accounting for Eq.(6) to enable one to be limited by the first term of the sum, we get for \( h = 0 \)

\[
I_0 = \frac{c p \beta}{\sqrt{2\pi(R^2 + M^2)}}. \tag{10}
\]

The ratio of Eq.(7) to Eq.(10) will give "smeared" jet size \( \sqrt{2\pi(R^2 + M^2)} \). It is also possible to use a theoretical estimate of R-value.

5.2. Comparing field lidar experimental results and mathematical model of impurity diffusion

The diffusion of a polluting impurity from real sources was computed according to the procedure of item 6 (WP07).

The calculations were compared with real distributions of pollutants by field lidar observations near emissive sources.

Figure 6 compares lidar experimental results\(^2\) and calculations of dust concentration spatial distributions emitted by a stack of a potassium enterprise. The measurements have showed that at distances 0.5 to 1 km from the stack the maximal concentration is about 2 mg/m\(^3\) with characteristic transversal dimensions of 200 and 40 m along the horizontal \( y \) and vertical \( z \) directions, respectively. The distribution of an impurity from a point source was computed in the plane normal to the wind direction at distances of 700 m from the stack. The stack height was 100 m, wind velocity 2.8 m/s at altitude of the weathercock, particle radius was assumed as 1 \( \mu m \). We believed weakly-stable atmospheric stratification to correspond to evening experimental conditions. Fig.6 shows that the calculations of the vertical dimensions agree fairly well with lidar data. The computed horizontal jet width was about 120 m to be less than the horizontal jet dimension. A possible reason for this is underestimated variance of direction fluctuations. Fig.7 compares maps of horizontal distributions of dust concentrations by lidar data\(^2\) and by the numerical simulation. The computed structure of the concentration field does not exactly coincide from the observed one. Apparently, the wind field was more complex during experiments owing to adjacent buildings to differ from that used for the calculations. Nevertheless, typical concentration values differ only twice.

For a number of cases, emissive sources are transient. The procedure to compare lidar and theoretical data for transient emissive sources will be commonly elaborated by the scientific groups of the Institute of Physics, NASB (P06) and the Institute of Atmospheric Optics, RAS (P02).

Preliminary results of data processing of comprehensive experiments show that the treatment of a finite threshold of impurity detection by the lidar method is needed to adequately describe a field experiment.

6. Mathematical simulation of pollutant propagation near emissive sources (within the scope of WP07, 3D model development)

6.1. Mathematical model of impurity propagation from transient sources

According to the approximation\(^3\), impurity concentration carried by a turbulent wind flux can be factorised as follows:

\[
c(x,y,z) = p(x,y)q(x,z), \tag{6.1.1}
\]

where \( c(x,y,z) \) is the impurity concentration at point \( (x,y,z) \) of a Cartesian coordinate system with \( x \)-axis directed along wind and \( z \)-axis directed vertically up. Quantity \( q \), which is the integral of the concentration along \( y \)-axis, is defined by the following equation

\[
u(z) \frac{\partial q}{\partial x} - w \frac{\partial q}{\partial z} = \frac{\partial}{\partial z} k(z) \frac{\partial q}{\partial z}, \tag{6.1.2}
\]
where \( u(z) \) and \( k(z) \) are the wind velocity and turbulent diffusion coefficient, respectively, \( w \) is the velocity of sedimentation of aerosol particles.

The boundary condition for a source located at \( x = 0, z = h \) can be written down as

\[
u(h)q(0, z) = M\delta(z - h), \quad (6.1.3)
\]

where \( M \) is the source power. The boundary condition over an underlying surface is

\[
\left( k(z) \frac{\partial q}{\partial z} + wq \right)_{z=0} - V_s q(0) = Q_s \quad (6.1.4)
\]

where \( V_s \) is the velocity of dry deposition, \( Q_s \) is the intensity of wind rise.

Analysis of experimental data has showed\(^3\) that for moderate distances from a source the transverse distribution of concentration \( p \) can be approximately expressed as

\[
p(x, y) = \frac{1}{\sqrt{2\pi \Delta \phi x}} \exp \left( -\frac{y^2}{2\Delta \phi x^2} \right) \quad (6.1.5)
\]

where \( \Delta \phi \) is the angular variance of wind direction fluctuations depending on atmospheric stratification, mean wind velocity, and observation duration \( t \). The dependence on observation duration can be approximated\(^1\) by \( \Delta \phi(t) \sim t^{-\frac{1}{4}} \). We use the Monin – Obukhov’s theory\(^4\) to compute profiles of wind velocity and turbulent diffusion coefficient in the near-ground atmospheric layer.

\[
\frac{\partial u}{\partial z} = \frac{u^*}{\chi z} \phi(z) , \quad k(z) = \frac{\chi u^* z}{\phi(z)} , \quad (6.1.6)
\]

\[
\phi = \begin{cases} 
1 + \beta \xi , & \xi \geq 0 \\
(1 - \gamma \xi)^{-\frac{1}{4}} , & \xi \leq 0
\end{cases}, \quad \xi = \frac{z}{L} , \quad L = \frac{TC_p \rho (u^*)^3}{\chi g H} , \quad (6.1.7)
\]

where \( u^* \) is the friction velocity, \( \chi \) is the Karman constant, \( \phi \) is the universal function approximated by Eq. (7), \( \beta \) and \( \gamma \) are constants, \( \beta = 6, \gamma = 16 \); \( T \) and \( \rho \) are the temperature and density of near-ground air, respectively, \( C_p \) is the air heat capacity, \( H \) is the turbulent vertical heat flux, \( g \) is the gravitational acceleration, \( L \) is the Monin – Obukhov's scale being a quantitative measure of atmospheric stability.

To determine wind velocity and diffusion coefficient at altitudes exceeding the near-ground boundary layer (its altitude is about 10 to 50 m), we use the following relations\(^3\):

\[
u = 2.5 \overline{u(z)} , \quad k(z) = 4u^* \lambda \overline{k(z)} , \quad (6.1.8)
\]

\[
\overline{z} = \frac{z}{\lambda} , \quad \lambda = 0.4 \frac{u^*}{l} , \quad (6.1.9)
\]

where \( l \) is the Coriolis parameter. The universal profiles of wind velocity \( \overline{u(z)} \) and turbulent diffusion coefficient \( \overline{k(z)} \) were proposed by L.N.Byzova et al.\(^6\) on the base of multi-year observations of meteorological parameters by a 300-m mast and numerical simulation of the
structure of the atmospheric boundary layer. These profiles depend on the atmospheric stability kind (stratification) that has been determined by the method of Turner – IEM

6.2. Mathematical model of impurity propagation from pulsed sources

The Lagrangian approach is used for mathematical simulation of impurity propagation from pulsed sources. According to the Gaussian statistical model, ensemble-averaged concentration $c$ in an instantaneously-formed impurity cloud can be estimated as

$$c(\tilde{x}, \tilde{y}, \tilde{z}, t) = \frac{Q}{(2\pi)^{3/2} S_x(t) S_y(t) S_z(t)} \exp \left[ -\frac{\tilde{x}^2}{2S_x^2(t)} - \frac{\tilde{y}^2}{2S_y^2(t)} - \frac{\tilde{z}^2}{2S_z^2(t)} \right], \quad (6.2.1)$$

where $\tilde{x}, \tilde{y}, \tilde{z}$ are the coordinates counted from the gravity center of the cloud, $\tilde{x}$-axis is directed along wind velocity, $\tilde{y}$- and $\tilde{z}$-axes does along the transversal and vertical directions, respectively, $S_x(t)$, $S_y(t)$, $S_z(t)$ are the mean-squared cloud dimensions, $Q$ is the total emitted impurity mass.

In the near-ground atmospheric layer, the vertical cloud dimensions increase with time by the following relation:

$$S_z^2(t) = S_z^2(0) + \Delta S_z^2(t), \quad (6.2.2)$$

where

$$\Delta S_u = a_1 u_*, t \quad \text{for neutral stratification,} \quad (6.2.3a)$$

$$\Delta S_u = a_2 u_*^{3/2} t^{1/2} L^{-1/2} \quad \text{for unstable stratification,} \quad (6.2.3b)$$

$$\Delta S_u = a_3 u_*^{1/2} t^{1/2} L^{1/2} \quad \text{for stable stratification,} \quad (6.2.3c)$$

where $u_*$ is the friction velocity, $L$ is the Obukhov’s scale, $a_1$, $a_2$, and $a_3$ are constants determined empirically, $a_1 = .30$ to .44; $a_2 = 1.0$ to 1.1; $a_3 = .20$. The dependencies of Eq.(3), but with other numerical constants describe also the vertical displacement of the cloud gravity center. The horizontal cloud dimensions across the wind are approximated by Naidenov’s formulas in the near-ground atmospheric layer

$$S_y^2(t) - S_y^2(0) = \bar{a}_1(u_*, t)^2 + \bar{a}_2 L^{-1}(u_*, t)^3 \quad \text{at } L < 0 , \quad (6.2.4a)$$

$$S_y^2(t) - S_y^2(0) = \bar{a}_3(u_*, t)^2 \left[ 1 + \bar{a}_4 L^{-1}(u_*, t) \right]^{-1} \quad \text{at } L > 0 , \quad (6.2.4b)$$

for $\bar{a}_1 = 0.176$; $\bar{a}_2 = 0.138$; $\bar{a}_3 = 0.29$; $\bar{a}_4 = 0.06$. The longitudinal cloud dimension was assumed to be equal to the transversal one.

Above the near-ground layer, in the region of quasi-uniform turbulence, the variance of particle coordinates with respect to the instantaneous gravity center can be expressed as

$$S_z^2(t) = S_z^2(0) + \Delta S_z^2(t_k) + .5 D_x^E(\delta_k) (\tau_x^v)^2 (1. - \exp(\eta))^2 + 2(w \tau_x^v)^2 (\eta - 1.5 - .5 \exp(-2\eta) + 2.\exp(\eta)) \quad (6.2.5)$$

where $t_k$ is the time moment of the cloud escape from the near-ground layer, $D_x^E(\delta_k)$ is the Eulerian structural velocity function, $\delta_k = \bar{S}_z(t_k)$, $\tau_x^v$ is the Lagrangian correlation time of the vertical velocity component of a liquid particle, $w$ is the mean-squared value of turbulent
pulsations of the vertical velocity component,

\[ \eta = (t - t_k) / \tau^w_L . \]  

(6.2.6)

If the cloud has appeared above the near-ground layer, then \( t_k = 0 \).

Horizontal cloud dimensions along and across wind above the near-ground atmospheric layer are determined by a formula similar to Eq.(5) with adding terms describing the cloud expansion due to the vertical shift of wind velocity and direction.

The height of the near-ground atmospheric layer is estimated by the following way\(^1\):

\[ h_0 = 30 \text{ m} \quad \text{for neutral stratification,} \]  

(6.2.7a)

\[ h_0 = .01H_m \sqrt{H_m / L} \quad \text{for unstable stratification,} \]  

(6.2.7a)

\[ h_0 = .28L \quad \text{for stable stratification,} \]  

(6.2.7c)

where \( H_m \) is the height of the mixing layer. Owing to the absent data, it is estimated by the relation\(^7\)

\[ H_m = Z_m 4u_*/f_{\text{COR}} , \]  

(6.2.8)

where \( f_{\text{COR}} \) is the Coriolis parameter, \( Z_m \) is a dimensionless coefficient depending on the stratification and season.

Since a real device can record only a concentration exceeding some value \( c_{\text{min}} \), the observable cloud dimensions and total mass of an emission will differ from the real ones. Within the scope of the Gaussian statistical model, observable mass \( M \) of emission is determined by

\[ M = Qm , \]  

(6.2.9)

where

\[ m = \int g \exp(-\xi) \text{erf}(\sqrt{g - \xi}) \ d\xi , \]  

(6.2.10)

\[ g = \ln(Q/c_{\text{min}}(2\pi)^{3/2}S_xS_yS_z) . \]  

(6.2.11)

Observable mean-squared cloud dimensions \( R_i \) are

\[ R_i = S_i \sqrt{1 - f/m} , \]  

(6.2.12)

where \( i \) denotes \( x, y, \) and \( z \),

\[ f = 4(3\sqrt{\pi})^{-1} g^{3/2} \exp(-g) . \]  

(6.2.13)

The observable cloud mass and dimensions are derived by the integration of the concentration, multiplied by the coordinate squared, over the region bounded by the condition of \( c \geq c_{\text{min}} \). The value of \( g \) decreases with increasing cloud dimensions or with decreasing ratio \( Q/c_{\text{min}} \). For this, observable cloud dimensions \( R_i \) and its mass \( m \) decrease. For \( g \leq 0 \), the cloud becomes indistinguishable.
7. Conclusion

During the second year of the Project execution partner P06 will work towards refining the lidar procedure for air monitoring in an industrial center and comparing lidar data with mathematical simulations (WP05 and WP07).

Field tests of the designed procedures will be carried out within the scope of task WP08.

The structure of output files and lidar database will be adapted to the specifications of the ISIREMM system within the scope of task WP06.

8. References


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Typical characteristics of lower 300-meter atmospheric layer obtained on mast measurements. Edit. N.L. Byzova, Gidrometeoizdat, Moscow, 1982.


9. Plans for the next year

WP05

• **Refining the procedure to lidar monitor pollutants of air basin over an industrial center.** There will be refined a lidar procedure to routinely monitor air pollution over an industrial center. The objective is to obtain general characteristics of spatial pollutant distributions of the air basin over an industrial center and to expose regions with higher pollution levels on the base of the analysis of routine field lidar measurements. The procedure of lidar monitoring and algorithms for data processing will be oriented towards gathering information to construct models of pollutant transport.

• **Validating the simulation results on pollutant transport from a pulse source.** There will be designed a procedure to compare lidar data with mathematical simulations of pollutant transport from a pulse source. The comprehensive investigations of spatial distribution of a suddenly-arising mixture cloud will be compared with computation results by using lidar and other sensors.

WP06

Design of lidar database.

There will be designed software to construct a lidar database. It should provide the archiving, ordering, and processing of source and roughly-processed lidar data files to transfer the lidar information to the ISIREMM database. The database will be structured by processing levels of lidar files starting from source files with digitised lidar signals and service parameters up to object levels with graphic and other information on spatial and temporal fields of atmospheric polluting components.

The adaptation of the database to the requirements of the ISIREMM system should be continued at stage 3b within the scope of tasks WP08 and WP09.

WP07

Elaboration of requirements to lidar data for their application in 3D models.

There will be elaborated requirements to the scales of spatial and temporal averaging of pollutant fields with using the lidar data to determine boundary conditions while simulating pollutant transport and testing the models.
Fig. 1. Mobile lidar station (MLS)
Fig. 2 Panoramic aerosol surveying lidar station
Fig. 3. Scheme of measurements of aerosol emissions near potassium enterprise No.2 (Soligorsk, Belarus)
Fig. 4. Calculated errors depending on distances between point of measurement and smoke stack.

Fig. 5. The difference $1-F(x)$, when the measurements are carried out off gas absorption band and at the absorption frequency, depending on doubled optical thickness of gas jet.
Fig. 6. At the top, measured distributions of particle concentrations in the vertical plane. Concentric closed curves bound the smoke jet. At the bottom, comparison of computed and measured distributions of particle concentrations in the jet along Y-axis (curve 1 and circles, respectively) and Z-axis (curve 2 and pluses).
Fig. 7. At the top, lidar-measured distributions of particle concentrations in the horizontal plane at territory 1 of potassium enterprise. At the bottom, calculated distributions of particle concentrations.
Introduction

Usefulness and end-user acceptance of similar complex systems highly depends on a simple and yet adequate and efficient presentation of data and results, simplification of processes for collecting the data and reliability of the different technical components.

The different tasks engaged aim at addressing delivery of data for analysis and presentation to the end-users as well as communication between different system components.

Communication means mainly based on WEB technologies will be contemplated, thus providing broadly available and usable tools to those different types of users identified within the ISIREMM environment. Work undertaken also addresses the identification, design and implementation of the technical architecture for modules communication (such as DBMS, simulation tools, data producers, Web server...)

Scientific and technical performance

Work undertaken in WP01

Major progress and achievements

Only a partial view of end user requirements related to displaying and presentation of data could be collected since no finalised version of the corresponding deliverable documents could be used in a first step.

Nevertheless, the overall progress of the work has not been significantly affected and synthesis of user needs and technical requirements could be initiated.

The technical architecture agreement includes the usage of LINUX servers as main platform for the system, and of MySQL, a royalty-free but yet efficient, open and portable database management system. The Internet is used as a federating communication mean. Web presentations are one of the required components of the system. In particular, different displays of time series of data are considered as a priority.

Work planned for the next period/remainder of the project

Consolidation of user requirements with the end-users partners shall be achieved. These requirements may be revised and refined according to feedback and test results on the prototyping done in WP6.
Major progress and achievements

First survey of the technologies and standards to be implemented has been initiated. Starting from an Airware-based system, main components of the ISIREMM architecture including Memo model and IAO’s models, a federating database coupled with a WEB server has been agreed.

First prototyping and tries related to data representation through navigator applets could be started. An Apache HTTP server will be used as powerful, secure market leading and free software component.

Following objectives have been met:

- Survey and familiarisation with basic system data formats (Airware/ECOSIM), technical documentation and references as well as results of the different models to be used in ISIREMM
- Review of state-of-the-art of basic techniques used for time series analysis, including identification of patterns using smoothing or curve fitting techniques. It leads to considering different types of displays combing graphical and numerical information.
- Implementation work conducted during the reporting period has covered first prototyping of generic-purposes applets. This shall allow for consultation and graphical representation of data and model results through HTTP. One of the objectives is to have portable code allowing usage of most navigators. They are implemented 100% in Java.

An example of applet representing several indicators with double scale and a dynamic values-pointer (numerical values appear by moving the mouse above the different points of the graphic) is shown below.

- Sources of data to be considered for the design of the communication infrastructure have been reviewed together with IAO. Meteo data through TOR / Tomsk / and two other possible sensor-stations, 6 to 10 air quality stations, stations for point source emission, stations for area source emission and sensors for linear source emissions. Precise procedures, resources and number of stations is still to be refined.

Progress versus plan, deviations, corrective actions

Design and implementation of the different components is mainly dependent on the consolidation of WP01 results, which have been slightly delayed.
Preliminary studies shall nevertheless start as soon as possible thanks to agreed improvements of communication between the involved partners (file exchange resources, regular reporting, process agreements).

**Work planned for the next period/remainder of the project**

Technical specifications and software requirements will be completed. First prototypes of communication software components will be developed and will be deployed on the system.

Provisioning of network and tools resources and of associated documentation will be checked and finalised in order to be ready to start system’s integration and testing.
ANNUAL REPORT
Natural Recourses Department of Tomsk Regional Administration (P08)
Totals of Contract ICA2-CT-2000-10024
Integrated System for Intelligent Regional Environmental Monitoring & Management
“ISIREMM”
01 October, 2000 – 31 September, 2001
(First year)

Introduction
The main task of the group of the Natural Resources Department of Tomsk Regional Administration (P08) is to prepare and compile data required for localization of the AirWare system. According to the Working Plan, group P08 performed studies within the frame of WP 01 “Requirements analysis and data compilation” mainly. Relevant objectives are: to analyse data requirements and data availability; to compile the basic data sets for the initial implementation and testing of the software system and develop a consistent set of background data for the indicator development, the scenario analysis and model applications. It also participated in performing WP 00, WP 01, WP 04 – WP 06 and WP 10.

2. Description of the work
WP00
Participation in project management meetings, main activity was aimed at coordination of the efforts inside the team and links with the partners, and regional data suppliers.

WP 01
The work includes the compilation and processing of the required data sets, partly already available, into the standard formats defined by the work package leader in consultation with the application partners. The conversion and pre-processing of data from the existing formats into the formats specified also was supervised, and assisted, where necessary, by NRD group.

Relevant Deliverables were prepared as well: D01.2 Data Availability Report (including electronic city map) and D01.3 Individual databases (meteorology, emission inventory, stack emissions).

The following local data important for modeling and for air quality determination were gathered: meteorological data sets from three State meteo-stations located at Tomsk Region as well as air quality measurement data sets from sixth points of Tomsk city for the whole 2000-year, updated industrial emission inventory for Tomsk city, updated Geo Information Systems (GIS) (electronic maps) for the three chosen territories. According an order of the Regional Administration Head this work was done with participation of relevant Regional organizations responsible for the environmental issues. Namely, meteorological and air quality data preparation was performed by the Regional Unit of the State Committee on Meteorology and Environmental Monitoring, industrial emission inventory was prepared by the Regional Unit of the State Committee on Ecology and GIS were prepared by State enterprise Tomskgeomonitoring.
After compilation of the data sets they were transformed into electronic form and pre-processed into Excel format with participation of the IAO group (P 02). Also required for model initiation local characteristics such as atmosphere stability classes, categories of land use, etc., were retrieved from these data sets with their participation. Pre-processed data sets as well as the retrieved characteristics were delivered to the Project coordinator (ESS, P 01) and placed at the Project WWW-site http://isiremm.iao.ru/.

**Geography information data**

Since the ISIREMM System is aimed to consider air quality in city limits as well as to take into account pollutant transport to and from the city on regional scale it requires geography information data for three domains, namely Tomsk city itself, Tomsk city and neighbouring suburbs and West Siberia. For the first two cases digital maps in the ArcView GIS 3.x format were prepared by the Tomskgeomonitoring enterprise and for the West Siberia territory an available digital map DCW in scale 1:100000 was used.

The city map (see Fig.1) is provided with layers described in the Table1.

<table>
<thead>
<tr>
<th>N</th>
<th>File name</th>
<th>Legend name</th>
<th>Code of land category</th>
<th>Name of land category</th>
<th>Initial coordinate system</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>DNA</td>
<td>ГИДРОГРАФИЯ</td>
<td>1</td>
<td>Water</td>
<td>Geographic</td>
</tr>
<tr>
<td>2</td>
<td>DNL</td>
<td>ГИДРОГРАФИЯ</td>
<td></td>
<td></td>
<td>Geographic</td>
</tr>
</tbody>
</table>

Fig.1.
<table>
<thead>
<tr>
<th></th>
<th></th>
<th>Geographic</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>DNLH</td>
<td>ГИДРОГРАФИЯ (БЕРЕГОВОЙ РЕЛЬЕФ)</td>
<td>Geographic</td>
</tr>
<tr>
<td>4</td>
<td>DNPU</td>
<td>ГИДРОГРАФИЯ (УРЕЗЫ ВОДЫ)</td>
<td>Geographic</td>
</tr>
<tr>
<td>5</td>
<td>PPA1</td>
<td>НАС. ПУНКТЫ (КВАРТАЛЫ)</td>
<td>Urban, Geographic</td>
</tr>
<tr>
<td>6</td>
<td>PPA2</td>
<td>НАС. ПУНКТЫ (СТРОЕНИЯ В КВАРТАЛАХ)</td>
<td>SubUrban, Geographic</td>
</tr>
<tr>
<td>7</td>
<td>PPA3</td>
<td>НАС. ПУНКТЫ (ОТДЕЛЬНЫЕ СТРОЕНИЯ)</td>
<td>SubUrban, Geographic</td>
</tr>
<tr>
<td>8</td>
<td>UTA</td>
<td>ИНФРАСТРУКТУРА</td>
<td>Urban, Geographic</td>
</tr>
<tr>
<td>9</td>
<td>UTL</td>
<td>ИНФРАСТРУКТУРА</td>
<td>Geographic</td>
</tr>
<tr>
<td>10</td>
<td>UTP</td>
<td>ИНФРАСТРУКТУРА</td>
<td>Geographic</td>
</tr>
<tr>
<td>11</td>
<td>HYA</td>
<td>РЕЛЬЕФ</td>
<td>Geographic</td>
</tr>
<tr>
<td>12</td>
<td>HYL</td>
<td>РЕЛЬЕФ</td>
<td>Geographic</td>
</tr>
<tr>
<td>13</td>
<td>HYP</td>
<td>РЕЛЬЕФ</td>
<td>Geographic</td>
</tr>
<tr>
<td>14</td>
<td>VGA</td>
<td>РАСТИТЕЛЬНОСТЬ</td>
<td>Forest, Geographic</td>
</tr>
<tr>
<td>15</td>
<td>VGL</td>
<td>РАСТИТЕЛЬНОСТЬ</td>
<td>Geographic</td>
</tr>
<tr>
<td>16</td>
<td>VGT</td>
<td>РАСТИТЕЛЬНОСТЬ</td>
<td>Geographic</td>
</tr>
<tr>
<td>17</td>
<td>SWA</td>
<td>БОЛОТА</td>
<td>Vegetation, Geographic</td>
</tr>
<tr>
<td>18</td>
<td>RDL</td>
<td>АВТОМОБИЛЬНЫЕ ДОРОГИ</td>
<td>Geographic</td>
</tr>
<tr>
<td>19</td>
<td>TSL</td>
<td>ДОРОЖНЫЕ СООРУЖЕНИЯ</td>
<td>Geographic</td>
</tr>
<tr>
<td>20</td>
<td>TSP</td>
<td>ДОРОЖНЫЕ СООРУЖЕНИЯ</td>
<td>Geographic</td>
</tr>
<tr>
<td>21</td>
<td>RRL</td>
<td>ЖЕЛЕЗНЫЕ ДОРОГИ</td>
<td>Geographic</td>
</tr>
<tr>
<td>22</td>
<td>RAMKA</td>
<td>РАМКА КАРТЫ</td>
<td>Geographic</td>
</tr>
<tr>
<td>23</td>
<td>people</td>
<td>Кварталы</td>
<td>Unknown</td>
</tr>
<tr>
<td>24</td>
<td>avenue</td>
<td>Улицы</td>
<td>Unknown</td>
</tr>
<tr>
<td>25</td>
<td>src 1+2</td>
<td>источники выбросов в атмосферу</td>
<td>Unknown</td>
</tr>
<tr>
<td>26</td>
<td>srcair</td>
<td>источники выбросов в атмосферу</td>
<td>Unknown</td>
</tr>
<tr>
<td>27</td>
<td>srcmax</td>
<td>источники выбросов в атмосферу</td>
<td>Unknown</td>
</tr>
<tr>
<td>28</td>
<td>srcwater</td>
<td>источники выбросов в гидросферу</td>
<td>Unknown</td>
</tr>
<tr>
<td>29</td>
<td>16600m-18600m_cell</td>
<td>ячейки сетки</td>
<td>Geographic</td>
</tr>
<tr>
<td>30</td>
<td>16600m-18600m_node</td>
<td>узлы сетки</td>
<td>Geographic</td>
</tr>
</tbody>
</table>
Typical cartographic layers 1-22 were prepared by Tomskgeomonitoring, while specific layers 23 – 31 with information supporting modelling efforts were prepared by the IAO group. Digital maps with all layers were passed to the project coordinator, files required for modelling support are placed at the project ftp.

**Meteorological data sets and retrieved characteristics**

Data from four meteorological stations in the vicinity of Tomsk (Bogashevo, Kozhevnikovo, Tomsk South and IAO SB RAS (East), the coordinates are fixed at the digital maps) were gathered to provide the ISIREMM Project with required background. Among gathered for the whole 2000-year data are wind velocity, temperature, humidity, pressure, cloud characteristics, etc. These data were transformed into electronic form and were prepared as EXCEL files. More general meteorological characteristics were determined in cooperation with the IAO group (P 02). These are stability classes and mixing heights. For their determination data from meteorological balloons, launched at Novosibirsk aerology station were used.

Examples of data formats are given below.

**Stability classes (2000 year): Data format**

<table>
<thead>
<tr>
<th>date/time</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
<th>16</th>
<th>17</th>
<th>18</th>
<th>19</th>
<th>20</th>
<th>21</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stability</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>B</td>
<td>F</td>
<td>A</td>
<td>A</td>
<td>C</td>
<td>E</td>
<td>D</td>
<td>A</td>
<td>E</td>
<td>E</td>
<td>D</td>
<td>E</td>
<td>D</td>
<td>C</td>
<td>C</td>
<td>B</td>
<td>C</td>
<td>B</td>
<td>C</td>
</tr>
</tbody>
</table>

Volume – 195Kb

**Mixing height (km): Data format**

<table>
<thead>
<tr>
<th>Month</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>10</td>
<td>11</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>0,30</td>
<td>1,20</td>
<td>1,20</td>
<td>1,37</td>
<td>1,19</td>
<td>2,10</td>
<td>2,00</td>
<td>2,20</td>
<td>1,00</td>
<td>0,62</td>
<td>1,20</td>
<td>0,82</td>
</tr>
</tbody>
</table>

Volume – 32Kb.

All pre-processed meteorological data were passed to ESS group (P 01) and placed at the project ftp thus giving all partner an access to it.

**Emission data**

All in all emission data required for air quality modelling include industrial point sources of emission (mainly stacks), linear sources of emission (city street segments with heavy traffic), area sources of dust and industrial emissions and VOCs point and area sources. These data were prepared by the Regional Unit of the State Committee on Ecology in unknown coordinates. Their positioning at the city digital maps was performed with IAO groups. General pattern of all sources of emissions in the city is shown on the Fig.2.
To provide the system developed with relevant supporting information main industrial sources of pollution in the city were chosen and described in the file Point sources of emission.

The data format is shown in the table below.

<table>
<thead>
<tr>
<th>id1</th>
<th>name1</th>
<th>id2</th>
<th>name2</th>
<th>px</th>
<th>py</th>
<th>pz</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Томская ГРЭС-2</td>
<td>1</td>
<td>труба</td>
<td>84,9969</td>
<td>56,4700</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sheight</th>
<th>Sdiam</th>
<th>Evel</th>
<th>Etemp</th>
<th>IDSubst</th>
<th>Subst name</th>
<th>Sheight</th>
<th>EM(mg/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>269</td>
<td>4,5</td>
<td>17,61</td>
<td>113</td>
<td>Пыль неорганическая</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>

px,py - (geographical coordinate in fraction of degree)

pz - altitude over the sea level

Sheight - point source height

Sdiam - diameter of source

Evel - emission velocity (m/s)

Etemp - temperature of upper part of stack (degree Centigrade)

EM (mg/s) - emission mass (milligram per second).

Names of plants, factories, type of stack and substances are given in Russian, data volume – 370Kb.

Closely placed small sources of industrial emissions were grouped into 12 area sources. Relevant file Area sources of emission has the following data format:
<table>
<thead>
<tr>
<th>ID</th>
<th>Name</th>
<th>ID_chem</th>
<th>Name_chem</th>
<th>mg/s</th>
<th>t/y</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area 1</td>
<td>АО Сибкабель эмальпроиз-во</td>
<td>101</td>
<td>Алюминия оксид</td>
<td>0,00042</td>
<td>0,01002</td>
</tr>
</tbody>
</table>

Location (geographical coordinates) and description of areas.
Names of plant and substances are given in Russian, the file volume – 360Kb.
Distribution of these sources in the city is shown on the Fig.3.

Fig. 3. Area sources of emission in Tomsk

Special work was organized jointly with IAO group to determine characteristics of linear sources of emissions. To this end heavy loaded with traffic streets of Tomsk city were chosen. These are shown on the Fig. 4.
To determine characteristics of the road segments (linear sources) two series of measurements (March and April-May) were performed. Processing their results is summarized in the file **Linear sources of emission**, whose format is shown below.

<table>
<thead>
<tr>
<th>No.</th>
<th>Point-to-point</th>
<th>Street width</th>
<th>Segment name</th>
<th>Speed km/h</th>
<th>Cars/h</th>
<th>Trucks/h</th>
<th>Buses/h</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1 &lt;-&gt;1 av</td>
<td>Нахимова</td>
<td>45</td>
<td></td>
<td>960</td>
<td>36</td>
<td>156</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Speed km/h</th>
<th>Length/m</th>
<th>X₁</th>
<th>Y₁</th>
<th>X₂</th>
<th>Y₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>60</td>
<td>1,507</td>
<td>84,9709</td>
<td>56,4545</td>
<td>84,9518</td>
<td>56,4551</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>No.</th>
<th>Point-to-point</th>
<th>Street width</th>
<th>Segment name</th>
<th>CO, winter (g/s)</th>
<th>CH, winter</th>
<th>NOₓ, winter</th>
<th>C, winter</th>
<th>Pb, winter</th>
<th>SO₂, winter</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1 &lt;- &gt;1 av</td>
<td>Нахимова</td>
<td>71548,30</td>
<td>15752,36</td>
<td>4912,36</td>
<td>151,64</td>
<td>76,85</td>
<td>871,94</td>
<td></td>
</tr>
</tbody>
</table>

Road segment (geographic coordinates, in a fraction of degree)
Street width - (v_n, N, av, wide, V-wide)
The segment names are given in Russian. The file volume is 970Kb.
To provide the photo-chemical modeling block of the system with data sources of VOC where
chosen from the whole set of polluting the area sources of VOCs and grouped into the following two sets: point and area VOC sources. Relevant file **Area and point VOC sources** was prepared in the following format.

**Area sources**

<table>
<thead>
<tr>
<th>no</th>
<th>name</th>
<th>Coordinates</th>
<th>Substance</th>
<th>mg/s</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>АООТ Т3РО</td>
<td>84.9426  56.5157</td>
<td>benzol</td>
<td>0.00128</td>
</tr>
<tr>
<td></td>
<td></td>
<td>84.9490  56.5157</td>
<td>petrol</td>
<td>39.151</td>
</tr>
<tr>
<td></td>
<td></td>
<td>84.9426  56.5114</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>84.9490  56.5114</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Point sources**

<table>
<thead>
<tr>
<th>no</th>
<th>name</th>
<th>Coordinates</th>
<th>Substance</th>
<th>mg/s</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Завод Метанол</td>
<td>84.9426  56.5157</td>
<td>Formaldehyde</td>
<td>0.00128</td>
</tr>
</tbody>
</table>

Geographic coordinates are given in fraction of degree, the file volume is 87Kb.

**Air quality data**

To provide modelling efforts with reference air quality monitoring data based on measurements performed by the Regional Unit of the State Committee on Meteorology and Environmental Monitoring were prepared and pre-processed. Results of measurements of chemical compound concentrations at 6 points of the city during 2000-year are prepared in the following form.

**Data format**

<table>
<thead>
<tr>
<th>month</th>
<th>date</th>
<th>hour</th>
<th>temp</th>
<th>dir</th>
<th>speed</th>
<th>phen</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>10</td>
<td>11</td>
</tr>
</tbody>
</table>

Dust SO2 CO NO2 NO C6H5OH Soot HCOH
-1 -3 0 -2 -2 -3 -2 -3
0.5 0 2 0 0 0 0 0

Chemical compound (Formula (Dust), under formula is a degree index -1 \((10^{-1})\), the index is the same for all concentrations in column). Concentration unit is \((\text{mg/m}^3)\). Concentration is product (for example, for Dust it is \(0.5\times10^{-1}\)). The file volume is 160Kb.

**City population distribution**

To provide the system with possibility to determine number of Tomsk citizens exposed to action of unfavourable air pollution influence during especially heavy situations data on the city population territorial distribution were gathered and pre-processed as well. These data form additional information layer (31 in the Table 1) for the digital map of Tomsk in ArcView GIS. This distribution is shown on the Fig. 5.
Here NRD activity was aimed at providing both historical and current data required for baseline simulations and at development a set of representative scenarios based on historical data. To this end air quality measurements during 2000-year were analysed, 12 “bad” cases belonging different seasons were determined and results were passed to WP 02 for subsequent synoptic description.

WP 05

Here the NRD group prepared regional base-line meteorological scenarios and relevant data in form adapted for test runs of models.

WP 06

Within this WP NRD activity is aimed at determination of system low-bandwidth remote user types and level of their access to the system, as well as at specification of their needs and their technical support.

WP 10

Here NRD group members using their position within the Tomsk Regional Administration publicized the project, its first results and potential benefits for regional managing bodies and population at regional and national level. Several papers were also delivered at National and international Conferences. Head of the Group Prof. R. Tukhvatulin participated in organization and run of ENVIROMIS 2000 Conference where special Session devoted to the ISIREMM project took place.

4. Conclusions

During the first year of the NRD Project activity relevant Deliverables were prepared: D01.2 Data Availability Report (including electronic city map) and D01.3 Individual databases (meteorology, emission inventory, stack emissions). The work resulted in a set of operational data collections that forms the basis of the subsequent analysis stages as well as those for deployment and initial testing of the first version of the system. Proper input was done to deliverables prepared within other work packages.
5. Publications and papers

6. Plan for the next year

WP00
In collaboration with partners NRD will assist Coordinator in coordination of the project activities.

WP01
During the second year updating of current data collections is planned. Special efforts are planned to be devoted to more detail description of polluting role of the transport, including diurnal and seasonal variations as well as to more precise description of city population distribution, including its day-time and night-time variations.

WP04
Efforts will be devoted to development of strategies/scenarios of city air quality improvement and their assessment on the base of historical and current data.

WP05
Participation in assessment of regional base-line meteorological scenarios and determination of environmentally “worst” cases is planned.

WP06
In collaboration with P02 online connection with the state owned sensor meteorological and air quality monitoring stations NRD group will be organized.

WP08
Regional assistance to relevant stages of system implementation and testing will be organized.

WP09
Participation in development of system test criteria is planned.

WP10
In collaboration with partners continue efforts aimed at dissemination of information on current project results and its potential usefulness anticipated.
ANNEX: MEETING REPORTS

First NIS Consortium Meeting Report

date: 24 October 2000,

place: Tomsk, Institute of Atmospheric Optics premises.

purpose: Discussion of NIS participants related part of the Project and the ISIREMM Project presentation to participants of ENVIROMIS 2000 international Conference

Environmental Observations, Modeling and Information Systems as tools for urban/regional pollution rehabilitation* and to the targeted audience from city and region administration.

Participants: IAO team members (Dr. Balin Y.S., Dr. Bogushevich A.Y., Dr. Fazliev A.Z., Golovko V.F., Prof. Gordov E.P., Dr. Krutikov V.A., Prof. Polichtchouk Yu. M., Prof. Starchenko A.V.);

ICMMG team members (Dr. Bushenkov Yu.M., Dr. Korotkov M.G., Prof. Penenko V.V., Dr. Tsvetova E.A., Dr. Yudin M.S.);

SRI team members (Mr. Akhmedzhanov A.K, Mrs. Dedova T.V., Dr. Kazmirchuk L.A., Mr. Sakhariev B.S.),

BISIP team members (Dr. Barun V.V., Dr. Chaikovskii A.P., Prof. Kabashnikov V.P.),

NRD team members (Dr. Adam A. Tomsk regional ecological Committee, Mr. Krivoshapko A.I., Tomsk Regional Hydrometeorology Committee, Prof. Tuhvatulin R.T., Mr. Zinenko V.N., West-Siberian Department of Russian Hydrometeorology Service, Novosibirsk).

The meeting took place at the IAO premises.

It was chaired by Gordov E.P., Prof., Institute of Atmospheric Optics SB RAS, Tomsk, Russia

Firstly general description of the ISIREMM Project WP was refreshed by E.P. Gordov. The IAO Director Dr. Sci. Matvienko G.G. continued it by description of IAO general activity in environmental studies and related it to the relevant work packages.

Description of SRI activity in development of geo-information system for air quality monitoring in Almaty city and its relation to assigned to SRI tasks was presented by Dr. Sakhariev B.S.

Usage of optical tools for air quality monitoring in city and industrial center was done by Pr. Kabashnikov V.P. from Institute of Physics NASB, Minsk, Belarus.

Results of numerical simulation of trans-regional pollutant transport on the base of original models and usage in the Project were presented by Pr. Penenko V.V., Institute of Computational Mathematics and Mathematical Geophysics SB RAS, Novosibirsk.

Practices concerning access to environmental data adopted at Tomsk Regional Administration environmental policy was described by Pr. Tuhvatulin R., Department of Natural Resources of the Tomsk Regional Administration Tomsk, Russia.

Then the general discussion took place.

It was summarized by Pr. Gordov E.P. In his summary mutually appropriate data formats, requirements and means of data exchange between Partners were fixed.
Project Kick-off Meeting

Date: 11 and 12 December 2000

Place: ESS offices, Gumpoldskirchen, Austria

Participants:

<table>
<thead>
<tr>
<th>Organisation</th>
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<tr>
<td>ESS</td>
<td>Kurt Fedra</td>
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<td>Lothar Winkelbauer</td>
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<td>IAO</td>
<td>Evgueni Gordov</td>
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<td>ICMMG</td>
<td>Vladimir Penenko</td>
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<td>SRI</td>
<td>Edige Zakarin</td>
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<td>BISIP</td>
<td>Anatoli Chaikovski</td>
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<td>SILOGIC</td>
<td>Benoît Baurens</td>
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<td>NRD</td>
<td>Ravil’ Tukhvatulin</td>
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The kick-off meeting did serve several important objectives:

- Establish a direct **personal relationship** between participants in a first face-to-face meeting, especially important for those that have not yet met and worked together;
- Establish the various committees and the **organisational and communication structures** for the project;
- Clarify project administrative matters such as **reports and cost statements**;
- Clarify technical details such as **data formats** for communication;
- Discuss the details of the **work plan implementation**, with emphasis on the first 12 months and the first set of Deliverables, preparing for the first **Project Review**;
- Fix a list of **ACTION ITEMS** for the detailed work plan for the coming months.

Meeting Agenda

**Monday, December 11, 2000**

09:00 Opening of the meeting:
Welcome
objectives and format of the meeting,
Introduction of participants

09:30 Nomination of Committee representatives, checking of contact details, etc.
(Project Steering Committee, Technical Steering Committee)

10:00 Discussion of Project Administration:
Reporting
Cost statements
Meetings (setting dates ...)
Communication (web server, mailing list, data formats, meta data)

11:00 Discussion of Work Programme by Work Packages:
WP 01: Requirements analysis and data compilation
12:00 Lunch
13:00 Discussion of Work Programme by Work Packages: WP 02 - WP 10
19:00 Joint dinner at a local vine tavern

Tuesday, December 12, 2000
09:30 Definition of a detailed PLAN OF ACTIONS and TIME TABLE and individual inputs and responsibilities for the next 12 months, bilateral technical meetings;
12:00 Discussion of future project meetings, tentative schedules
13:00 Any other topic

Second NIS Consortium Meeting Report

Date: 25-26 June 2001
Place: Irkutsk, Limnology Institute premises

Purpose: Discussion of current state of the art and problems appeared in performance of NIS participants related part of the Project and the ISIREMM Project presentation to participants of MODAS 2001 “International Conference on Modeling, Databases and Information Systems for Atmospheric Sciences”.

Participants: IAO team members (Mr. Babikov Yu.L., Dr. Balin Y.S., Dr. Bogushevich A.Y., Dr. Fazliev A.Z., Golovko V.F., Prof. Gordov E.P., Dr. Krutikov V.A., Prof. Polichtchouk Yu. M.);
ICMMG team members (Mrs. Boyarshinova E.A., Prof. Penenko V.V., Ms. Pozdnyakova N.S., Ms. Zinovieva I.V.);
SRI team members (Dr. Ismailova B.B., Dr. Kazdayev N.Kh., Pankratov V., Prof. Zakarin E.A.),
BISIP team members (Dr. Chaikovskaya L.I., Dr. Chaikovskii A.P., Academician Ivanov A.P., Prof. Kabashnikov V.P.),
NRD team members (Mr. Kolotovkin I.V., West-Siberian Department of Russian Hydrometeorology Service, Novosibirsk).

The meeting took place at the Limnology Institute premises during breaks in the MODAS Conference. During the first seating main problem encountered during the project execution were described. Profs. V. Penenko (ICMMG) and A. Starchenko (IAO) formulated their pollutant transport model requirements to input data, both to meteorological characteristics and land use categories. Mr. I. Kolotovkin (NRD), Dr. A. Chaikovskii (BISIP) and Dr. Yu. Balin (IAO) described specifics of meteorological data both coming from the state hydrometeorological stations and retrieved from lidar measurements. Prof. E. Zakarin (SRI) described character of acoustic sounding data as well existing possibility to determine land use category from satellite images. He also mentioned problems, which should be solved to determine those for Tomsk city neighborhood and for Tomsk Region.

During the second day seating Dr. Sci. V. Krutikov (IAO) suggested an approach to be used to provide modelers with data required. Subsequent general discussion refined his approach.

In concluding remarks Pr. E. Gordov listed encountered by NIS Partners problems, which appeared in process of data exchanges concerning data format requirements and means of their transportation were summarized. A way to pass data from Kazakhstan to Tomsk and backward was suggested. Particular measures to accelerate partner inputs to task performance were suggested and adoption by the Partners.
DATA SHEET

Project: ISIREMM - Integrated System for Intelligent Environmental Monitoring & Management
Contract Number: ICA2-CT-2000-10024
Reporting Period: 01.10.2000 - 30.09.2001

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2. Training:
- number of PhDs | 0   |
- number of MScs | 6   | 3   | 9    |
- number of visiting scientists | 6   | 6   | 12   |
- number of exchanges of scientists | 0   |

3. Achieved results:
- number of patent applications | 0   |
- number of patents granted | 0   |
- number of companies created | 0   |
- number of new prototypes/products developed | 0   |
- number of new tests/methods developed | 2   | 1   | 1   | 4   |
- number of new norms/standards developed | 0   |
- number of new softwares/codes developed | 3   | 4   | 1   | 2   | 10   |
- number of production processes | 0   |

4. Industrial aspects
- industrial contacts (Yes/No) | no  | yes | yes | no  | no  | no  | no  | no  | yes  |
- financial contribution by industry (Yes/No) | no  | yes | yes | no  | no  | no  | no  | no  | yes  |
- industrial partners - Large (Yes/No) | no  | no  | no  | no  | no  | no  | no  | no  | no   |
- industrial partners - SME (Yes/No) | no  | yes | no  | no  | no  | no  | no  | no  | yes  |

5. Comments
- other achievements

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