Environment Protection Engineering

Vol. 33 2007 No. 4

MARIA T. MARKIEWICZ*

METHODS OF DETERMINING METEOROLOGICAL DATA USED IN AIR POLLUTION DISPERSION MODELS

The methods of determining meteorological data used in air pollution dispersion models are classified and each class is described. Relationships between these methods and different groups of air pollution dispersion models are presented.

1. INTRODUCTION

The modelling of atmospheric processes consists in determining the atmospheric flow of air pollutants and in calculating their concentrations. This can be done either as an on-line modelling or an off-line modelling.

In the case of the on-line modelling, it is assumed that meteorological processes and pollutant concentration fields interact with each other. A meteorological model and an air pollution dispersion model create an air pollution dispersion system in which information is exchanged in two directions.

In case of the off-line modelling, it is assumed that meteorological processes influence pollutant concentration fields, but pollutant fields do not influence meteorological processes. A meteorological model supplies to an air pollution dispersion model with meteorological data, but the models are run separately.

The off-line modelling has some advantages and limitations. Among the advantages is the possibility of running different air pollution dispersion models or a specific model with different emission scenarios using the same meteorological data obtained from one simulation of the meteorological model. The disadvantage of such a modelling is that it needs accumulating and storing meteorological fields for long-term simulations. Some additional problems appear when calculation grids of meteorological and air pollution models differ. It has to be mentioned that the on-line

---

* Institute of Environmental Engineering Systems, Warsaw University of Technology, 00-665 Warszawa, ul. Nowowiejska 20, Poland.

modelling was introduced to air pollution dispersion studies in the mid nineteen nineties and up till now it has been applied rather rarely.

Up-to-date studies have shown a small influence of the on-line modelling on final results. It has to be taken into account, however, that in some situations a feedback takes place and the off-line modelling can be responsible for additional errors.

In this article, the methods of determining meteorological data used in air pollution models are discussed. The relationships between meteorological techniques and air pollution dispersion models are presented.

2. METHODS OF DETERMINING METEOROLOGICAL FIELDS

2.1. GENERAL REMARKS

There is a great variety of methods of determining meteorological fields. They differ in the complexity, requirements of computer capabilities as well as in the level of the user experience and skills. In general, the following techniques can be distinguished [1]:

- traditional methods,
- meteorological pre-processors,
- diagnostic meteorological models,
- prognostic meteorological models.

2.2. TRADITIONAL METHODS

These methods are the most simple and the oldest ones. They can be itemized as follows [1]:

- schemes of the determination of stability classes,
- the determination of the vertical wind profile using a power law relationship,
- the determination of the boundary layer height based on a statistics relating it to a stability class.

In the determination of atmospheric stability, the following sets of parameters can be used:

- the wind velocity, sun radiation intensity and cloud cover,
- the measurements of wind direction fluctuations,
- the vertical temperature gradient,
- the gradient Richardson number,
- the bulk Richardson number,
- the Monin–Obukhov length, surface roughness parameter,

- the ratio of wind velocities measured at two different heights.

The most famous method of determining atmospheric stability classes is the scheme of PASQUILL [2]. In this classification, six stability classes are distinguished. Such stability classes as very unstable, unstable and slightly unstable are assigned the letters: A, B, C. The letter D represents the neutral stability class. Slightly stable and stable conditions are given the letters E and F. Parameters needed to determine a type of the stability class are supplied by routine meteorological stations. They include the wind velocity, sun radiation intensity and cloud cover. The method of determining the stability classes used in Poland was developed by Hydro-Meteorological Institute. It is based on the same set of parameters as the Pasquill method and can be used for preparing a catalogue of meteorological data for meteorological stations in Poland. Other methods of determining the stability classes are given, for example, in SORBJAN [3] or EPRI study report [4].

In the determination of the vertical wind velocity profile, a power law empirical relationship is used. A vertical distribution of the wind velocity depends on the value of its power and varies for different stability classes [1], [3].

The determination of the boundary layer height is based on vertical profiles of meteorological parameters. Most often the vertical temperature profile from an aerological sounding is used and the boundary layer height is determined applying an air-dried parcel method of HOLZWORTH [5].

Applying this or other simple methods it is possible to determine an average height of boundary layer in a given class of atmospheric stability and to use this value in a simple air pollution dispersion model if more detail information is not available. Average heights of boundary layers in Poland were evaluated by LITYŃSKA [6].

The meteorological data obtained based on traditional methods are grouped together in order to calculate the air pollutant concentration in a different manner, depending on whether it is a short-term or a long-term simulation. In the case of the short-term simulations, the meteorological data are arranged in a chronological order (hour by hour). In the case of the long-term simulations, the meteorological data are usually prepared as a statistics of the occurrence frequency of meteorological parameters. Most often the three-dimensional statistics of the occurrence frequency of the wind velocity, wind direction and atmospheric stability class are prepared (wind roses) [7], [8].

In Poland, such statistics were developed by HMI for the decade of 1966–1975 for 58 meteorological stations and 8 measuring periods per day [8]. These statistics are available for the whole average year, summer season and winter season.

2.3. METEOROLOGICAL PRE-PROCESSORS

A meteorological pre-processor is a set of calculation algorithms used to determine atmospheric boundary layer parameters and vertical profiles of the wind and temperature based on the data from surface meteorological stations and aerological measurements. Data from the meteorological station are usually supplied every hour.

The measurements of the wind and temperature at different heights above the surface are obtained from the aerological station at least twice a day.

Meteorological pre-processors are considered to be a step forward in traditional methods of determining meteorological conditions. They improve the quality of air pollution dispersion simulations [9].

The following basic boundary layer parameters are distinguished [9]:

- the vertical heat flux (H_o),
- the vertical momentum flux (τ_o),
- the boundary layer height (h_{bl}).

The additional boundary layer parameters are:

- the friction velocity scale (u_*),
- the convection velocity scale (w_*),
- the Monin–Obukhov length scale (L),
- the potential temperature scale (θ_*).

The metod of van Ulden, Holtslag and de Bruin [10] is one of the most famous methods of determining boundary layer parameters. It includes the following modules:

- the determination of the surface roughness length (z_o),
- the calculation of the friction velocity scale (u_*), potential temperature scale (θ_*) and the Monin–Obukhov length scale (L),
- the reconstruction of the vertical wind profile,
- the determination of the boundary layer height (h_{bl}).

The surface roughness (z_o) describes aerodynamical features of homogeneous terrain. In the case of differences in the surface characteristics, the effective aerodynamical roughness is used. HOLTSLAG and van ULDEN [9] describe the following calculation methods of this parameter:

- a method, in which the vertical wind profile observed in the neutral atmospheric stability is used,
- a method of WIERINGA [11], in which the normalised standard deviation of the wind velocity (σ_u/u) is used,
- a method, in which the value of aerodynamical roughness is evaluated based on the visual terrain description and the values of z_o assigned to the specific terrain types following the Wieringa classification.

In the case of big differences in the surface characteristics, an area around the meteorological station should be divided into sectors and the surface roughness parameter should be determined for each sector separately. The value of z_o from a sector related to the meteorological flow should be used in calculations.

HOLTSLAG and van ULDEN [9] give two methods of determining the friction velocity (u_*), potential temperature scale (θ_*) and the Monin–Obukhov length scale (L):

- a method, in which vertical profiles of the wind and potential temperature in the surface layer are used,

- a method, in which the heat balance equation at the earth surface is used.

In the first method, the measurements of the wind velocity on one level in the surface layer and potential temperature on two levels are needed. In the second method, the information about the heat balance at the earth surface is used instead of the potential temperature measurements.

The difference between those two methods lies in the way of calculating the potential temperature. In the first method, it is given by $\theta_* = f_1(\Delta\theta, u_*)$ while in the second method – by $\theta_* = f_2(cl, \Theta_s, T, u_*)$.

The vertical wind profile is reconstructed using the Monin–Obukhov probability theory.

The methods of determining the boundary layer height depend on the atmospheric stability. In the case of the stable and neutral boundary layer, HOLTSLAG and van ULDEN [9] propose diagnostic equations. In the case of the convective boundary layer, they use a prognostic model based on a set of three ordinary differential equations.

Meteorological pre-processors gradually replace the traditional methods of determining meteorological data. This tendency has been observed in West European countries and in the USA since the mid nineteen eighties [12]–[18].

A meteorological pre-processor is usually developed together with an air pollution model. Here such pre-processors serve as the examples of the following modelling systems: the OML [19], HPDM [20]–[21], ADMS [22]–[23], MEPDIM [24], AERMOD [25].

A concept of a meteorological pre-processor developed in Poland is described in the paper of ŁOBOCKI and ULIASZ [26]. However, it was not implemented, since we face some problems with the application of meteorological pre-processors in Poland. They are connected with the sparse aerological network. The aerological soundings are carried out only in Legionowo, Poznań, Wrocław and Łeba.

Specific meteorological pre-processors differ in the methods of determining the boundary layer parameters. In the case of the dynamic velocity scale (u_*), potential temperature scale (θ_*) and Monin–Obukhov length scale (L), either one of two methods described by HOLTSLAG [10] or two methods are used. The reconstruction of the vertical wind profile is based on the Monin–Obukhov probability theory; however, different forms of universal functions are applied. In the case of determining the boundary layer height, greater diversity is observed. A review of the determination methods of this parameter presents SEIBERT et al. [27].

2.4. NUMERICAL, METEOROLOGICAL DIAGNOSTIC MODELS

A meteorological diagnostic model generates stationary meteorological fields based on measurements from surface meteorological stations. Usually only wind fields are supplied. A quality of wind fields depends on the measuring network density, frequency of observations and measuring quality. Meteorological diagnostic models cannot forecast the wind field forward in time.

In meteorological diagnostic models, usually only some of equations representing the atmospheric processes are used to determine the relationships between meteorological variables. These equations are in a steady-state form. Most often only the steady-state continuity equation is used as a physical constraint to generate the wind field [28]–[30].

Special algorithms describing the effects of a complex topography can be built into meteorological diagnostic models. These include the blocking and deflection of the air flow by local terrain barriers as well as the up-slope and down-slope flow through the heating and cooling of slopes [28].

Based on a meteorological diagnostic model it is possible to determine in two steps the wind field. The first step supplies an "initial wind field" at discrete points of the calculation grid by interpolation/extrapolation of wind velocity measurements from meteorological stations. The second step supplies a "final wind field" which fulfils the constraint [29].

Meteorological diagnostic models have some advantages and disadvantages. First of all they are easy and cheap to run. They can be run in a real time, which is very important in the case where the results are needed quickly. There is no accumulation of errors with time because the wind field for each hour is calculated based on different set of measuring data.

Table 1

Examples of the meteorological diagnostic models

Diagnostic models	Prognostic models
1. Model name 2. Institution	1. Model name 2. Institution
1. MATHEW [31] 2. Lawrence Livermore National Laboratory, USA	1. MM5 (Mesoscale Meteorological model) [42] 2. NCAR, USA
1. ATMOS1 (ATMOSpheric transport model for complex terrain) [32] 2 Los Alamos national laboratory	1. RAMS (Regional Atmospheric Modelling System) [43] 2. Colorado State University, USA
1. CIT (California Institute of Technology wind model) [33] 2. California Institute of Technology, USA	1. TVM (Topographic Vorticity Model) [44] 2. Joint Research Centre, Italy, Universite Catholique Louvain, San Jose State University, USA
1. CALMET (CALifornia METeorological model) [34] 2. Earth Technical Incorporation, USA	1. MC2 (*Canadian Mesoscale Compressible Community model*) [45] 2. University of Quebeck, Canada

Diagnostic models, however, suffer from some drawbacks. Although the wind fields determined by these models fulfil constraints, they do not always fully represent situations met in the real atmosphere. This is due to the fact that only a steady-state continuity equation is usually used as a physical forcing. These models do not prove correct in the areas with sparse measuring network such as mountains or oceans. The space and time structure of the fields obtained from these models is limited by the structure of the input data. This is a problem due to the fact that the meteorological network is usually too sparse to distinguish between some features, e.g., between the sea breeze and down mountain winds as well as between many regional features. In order to obtain the wind field of a finer structure, special expensive meteorological measurements have to be organised which allow the density and frequency of observations to be intensified. Despite these limitations meteorological diagnostic models are attractive in the case of long-term air quality assessments [28].

The examples of diagnostic meteorological models are given in table 1.

2.5. NUMERICAL METEOROLOGICAL PROGNOSTIC MODEL

A meteorological prognostic model allows a set of 2-dimensional or 3-dimensional equations describing the processes in the atmospheric boundary layer to be solved numerically. It provides information on fields of the wind, turbulence and other meteorological variables under specific terrain conditions. These fields can change with time and in space [28], [30].

Many of prognostic models currently used in air-quality assessments were designed to forecast complex atmospheric conditions. In their development, the attention was focused on the deep convection and strong dynamical forcing. The adaptation of models to the situations with the week dynamics is usually simple. In order to obtain accurate solutions, a very good parameterisation of atmospheric processes is needed. These processes are as follows: the moist convection; cloud, fog and precipitation formation; radiation; processes taking place at the earth surface; and turbulence processes. In prognostic models, the topography, different types of surface characteristics, urban areas as well as big water reservoirs are taken into account [29].

Meteorological prognostic models can be divided into hydrostatic and nonhydrostatic ones. In hydrostatic models, it is assumed that the vertical motion of atmospheric air is of a hydrostatic nature. This means that a gravitational force balances the action of a vertical component of a pressure gradient. In nonhydrostatic models, the pressure is determined using a more general method. In this method, the equation describing the vertical motion of atmospheric air, state equation and potential temperature equation are used [35].

The calculation of meteorological fields by prognostic models is made in two steps. The first step includes: the choice of the co-ordinate system, the choice of the integration method of equations describing the atmospheric processes, the determination of the modelling domain and its discretization, the determination of initial and boundary conditions. In the second step, a set of partial differential equations is solved numerically.

Meteorological prognostic models have advantages and drawbacks. One of the advantages of these models is that their application is limited only by the lack of computer hardware. Prognostic models do not require such a big amount of measurement data as the diagnostic models in order to obtain the meteorological fields of the same quality. Prognostic models, in which a fine grid is used, simulate the features characteristic of local or regional scale unresolved by observations. These features are simulated as a result of internal dynamics and topographic forcings. In prognostic models, physical processes affecting in a subscale meteorological fields can be represented. These processes are as follows: the moist convection; clouds, fog and precipitation formation; radiation; surface fluxes and turbulence. Prognostic models can be used to study specific processes because simulations can be repeated many times.

We should be aware, however, that prognostic models have their limitations. They are more expensive in comparison to diagnostic models as the integration of a set of nonlinear equations with a small step requires fast computers. However, this disadvantage will be slighter with the passage of time due to the progress in computer resources and numerical techniques. The measuring data are used only in the first stage of the prognostic model simulation. As a consequence, the modelling errors accumulate over time. These errors are due to imperfections of the calculation scheme, parameterisation method and initial conditions. In practice, the forecasts obtained from traditional prognostic models usually should not exceed 48 hours. Prognostic models are complex systems. In order to run them and interpret results, a special training is needed. In order to adapt these models to new modelling areas, a detailed knowledge of the terrain is necessary [28].

The number of modelling errors can be reduced by the four-dimensional data assimilation (FDDA). In this method, the measuring data from different time and space points are constantly used to correct prognostic model solutions. This method becomes more and more popular in air quality studies. It can be used in hydrostatic and nonhydrostatic models. It is especially valuable in the case where meteorological fields of good quality are needed. FDDA method is described by SEAMAN [29], STAUFFER and SEAMAN [36], STAUFFER et al. [37], STAUFER and SEAMAN [38], SEAMAN et al. [39], ARDAO-BADEJR and STAUFFER [40], and BARNA and LAMB [41].

The examples of prognostic meteorological models are given in table 1.

3. RELATIONSHIPS BETWEEN METEOROLOGICAL TECHNIQUES AND AIR POLLUTION DISPERSION MODELS

Air pollution dispersion models can be classified based on different criteria. Here the mathematical criteria are applied. Taking into account a type of the co-ordinate system, two groups of models are distinguished: 1. Lagrangian models in which the dispersion of air pollutant is described in the co-ordinate system travelling with air masses and 2. Eulerian models in which the co-ordinate system is fixed to the ground.

Because of practical reasons the Gaussian-type models are separated from the Lagrangian model group and they form the independent third group. These three groups of models are further divided, applying the model assumptions as a criterion. A detailed characteristic of each of the distinguished groups of air pollution models is given by MARKIEWICZ in [1], [46]. In table 2, the classification of models is presented.

Table 2

Classification of air pollution dispersion models based on mathematical criteria

Model group (basic classes)	Air pollution dispersion models
Eulerian models	Box models
	Analytical models
	Numerical, 1st-order closure models
	Numerical, higher-order closure models
	Large-scale eddy simulation models
Lagrangian models	Box models
	Particle models
Gaussian models	Traditional plume models
	New generation models
	Segmented plume or puff models

Table 3

Relationships between meteorological methods of the determination
of meteorological data and air pollution dispersion models

Meteorological methods	Air pollution dispersion models
Traditional methods	Traditional Gaussian plume models Segmented Gaussian plume or Gaussian puff Eulerian box models Eulerian analytical models
Meteorological pre-processors	New-generation Gaussian plume models
Meteorological diagnostic models	Eulerian numerical models with the 1st-order closure Eulerian box models Lagrangian box models Segmented Gaussian plume or puff models
Meteorological prognostic models	Eulerian numerical models with the 1st- and higher-order closure Eulerian large-scale eddy simulation models Lagrangian particle models

In table 3, the relationships most often established between meteorological techniques and air pollution models are given. Usually, the more complex the air pollution dispersion model, the more complex the method of determining meteorological data. A main criterion of choosing a meteorological technique is a guarantee that all the meteorological data needed for air pollution dispersion model are supplied.

4. SUMMARY

Air pollution dispersion models need different types of data such as the emission data, meteorological data, physiographic data. The air pollution dispersion models can be supplied with meteorological data by traditional methods, meteorological preprocessors, meteorological diagnostic models and, meteorological prognostic models.

It can be noticed that usually the more complex the air pollution dispersion model, the more advanced the method of determining meteorological data.

REFERENCES

[1] MARKIEWICZ M., *The fundamentals of air pollution dispersion modelling* (in Polish), Warsaw University of Technology Publishing Office, Warsaw, 2004.

[2] PASQUILL F., *The estimation of the dispersion of windburn material*, Meteorol. Magazine, 1963, 90.

[3] SORBJAN Z., *Turbulence and diffusion in the lower atmosphere* (in Polish), PWN, Warszawa, 1983.

[4] LIU M.K. et al., *Survey of plume models for atmospheric applications*, EPRI EA-2243, Report 1669-9, Systems Applications, Inc., 1982, Paolo Alto.

[5] HOLZWORTH C.G., *Estimates of mean maximum mixing depths in the contiguous United States*, Mon. Weather Rev., 1964, 92, 235–242.

[6] LITYŃSKA Z., *Determination of the boundary height and the wind shear for Pasquill stability classes based on the data from the four aerological stations and chosen synoptic stations located in Poland for the period of 1966–1980* (in Polish), technical report prepared for Warsaw University of Technology, 1985, PR-8 7.2.2.2, Warsaw.

[7] CHRÓŚCIEL St., *Calculation of the air contamination based on the ministry guidance* (in Polish), Protection of the Atmosphere, 1985, PZiTS, XIII, 470, Warszawa.

[8] *A meteorological catalogue IMGW* (in Polish), MAGTOS, Warsaw, 1979.

[9] HOLTSLAG A.A.M., VAN ULDEN A.P., *A simple scheme for daytime estimates of the surface fluxes from routine weather data*, J. Climate Appl. Meteorol., 1983, 22, 517–529.

[10] HOLTSLAG A.A.M., *Estimation of atmospheric boundary layer parameters for diffusion applications*, J. Climate Appl. Meteorol., 1985, 24, 1196–1207.

[11] WIERINGA J., *Estimation of mesoscale and local scale roughness for atmospheric transport modelling*, Proceedings from the 11th International Conference on "Air Pollution Modelling and its Application", November, 1980, Amsterdam, the Netherlands, Plenum Press, New York, 1981, 279–295.

[12] Proceedings of the workshop on "Objectives for Next Generation Practical Short-Range Atmospheric Dispersion Models", editors: Olesen H.R., Mikkelsen T., Riso, Denmark, May, 1992.

[13] Proceedings of the workshop on "Intercomparision of Advanced Practical Short-Range Atmospheric Dispersion Models", editor: Cuvelier C., Manno, Switzerland, September, 1993, Joint Research Center, Ispra.

[14] Proceedings from the workshop on "Operational Short-Range Atmospheric Dispersion Models for Environmental Impact Assessment in Europe", editors: Kretzschmar J., Maes G., Cosemans G., Belgium, November, 1994, published in: International Journal of Environment and Pollution, 1995, 5.

[15] Proceedings of the workshop on "Harmonisation within Atmospheric Dispersion Modelling for Regulatory Purposes", Ostend, Belgium, May, 1996, published in: International Journal of Environment and Pollution, 1997, 8.

[16] Proceedings of the workshop on: "Harmonisation within Atmospheric Dispersion Modelling for Regulatory Purposes", Rodos, Greece, May, 1998, published in: International Journal of Environment and Pollution, 2000, 14.

[17] Proceedings of the workshop on: "Harmonisation within Atmospheric Dispersion Modelling for Regulatory Purposes", Rouen, France, October, 1999, published in: International Journal of Environment and Pollution, 2001, 16.

[18] Proceedings of the workshop on: "Harmonisation within Atmospheric Dispersion Modelling for Regulatory Purposes, Belgirate, Italy, May, 2003.

[19] OLESEN H.R. et al., *An improved dispersion model for regulatory use – the OML*, Proceedings from the 19th International Conference on "Air Pollution Modelling and its Application", editors: Van Dop H., Kallos G., Ierapetra, September, 1991, Plenum Press, New York.

[20] HANNA S.R., PAINE J.R., *Hybrid plume dispersion model (HPDM) development and evaluation*, J. Appl. Meteorol., 1989, 28, 206–224.

[21] HANNA S.R., CHANG J.C., *HPDM improvements and testing at three field sites*, Atmos. Environ., 1992, 27A, 1491–1508.

[22] CARRUTHERS D.J. et al., *UK atmospheric dispersion modelling system*, Proceedings of the 19th NATO/CCMS International Conference on: "Air Pollution Modelling and Application", editors: Van Dop H., Steyn D.G., September, 1991, Ierapetra, Greece, Plenum Press, New York.

[23] CARRUTHERS D.J. et al., *Validation of ADMS against wind tunnel data of dispersion from chemical warehouse fires*, Atmos. Environ., 1999, 33, 1973–1953.

[24] BOHLER T., GUERREIRO C., *Verification of the meteorological pre-processor MEPDIM*, Proceedings from the 4th workshop on "Harmonisation within Dispersion Modelling for Regulatory Purposes", May, 1996, Belgium.

[25] LEE R.F. et al., *AERMOD – the development evaluation*, Proceedings from the 21st international conference on "Air Pollution Modelling and its Application", editors: Gryning S.E., Schiermeier F.A., November, 1995, Baltimore, Maryland, USA, Plenum Press, New York.

[26] ŁOBOCKI L., ULIASZ M., *A method of boundary layer parameters determination based on the data from routine meteorological station. Technical report* (in Polish), Warsaw University of Technology, Warsaw, 1989.

[27] SEIBERT P. et al., *Mixing height determination for dispersion modelling*, Report of working group 2, COST Action 710. Pre-processing of meteorological data for dispersion modelling, 1997.

[28] RATTO C.F. et al., *Mass consistent models for wind fields over complex terrain: the state of the art*, Materials from the Summer School in Truest, 1994, Institute of Theoretical Physics.

[29] SEAMAN N.L., *Meteorological modelling for air-quality assessments*, Atmos. Environ., 2000, 34, 2231–2259.

[30] SEINFELD J.H., *Ozone air quality models. A critical review*, J. Air Pollut. Assoc., 1988, 38, 616–623.

[31] SHERMAN C.A., *A mass-consistent model for wind fields over complex terrain*, J. Appl. Meteorol., 1978, 17, 312–319.

[32] DAVIS C.G. et al., *Atmospheric transport models for complex terrain*, J. Clim. Appl. Meteorol., 1984, 23, 235.

[33] GOODIN W.R. et al., *A comparison of interpolation methods for sparse data: application to wind and concentration fields*, J. Appl. Meteorol., 1979, 18, 761.

[34] SCIRE J.S. et al., *A user quide for the CALMET meteorological model*, Earth Tech. Inc., Concord, MA, 1977.

[35] PIELKE R.A., *Mesoscale meteorological modelling*, Academic Press, Inc, New York, 1986, 2002.

[36] STAUFFER D.R., SEAMAN N.L., *Use of four-dimensional data assimilation in a limited-area mesoscale model.* Part I. *Experiments with synoptic-scale data*, Mon. Weather Meteorol., 1990, 33, 416–434.

[37] STAUFER D.R. et al., *Use of four-dimensional data assimilation in a limited-area mesoscale model.* Part II. *Effects of data assimilation within the planetary boundary layer*, Mon. Weather Meteorol., 1991, 119, 734–754.

[38] STAUFFER D.R., SEAMAN N.L., *Multiscale four-dimensional data assimilation*, J. Appl. Meteorol, 1994, 33, 416–434.

[39] SEAMAN N. L. et al., *Multiscale four-dimensional data assimilation system applied in the San Joaquin Valley during SARMAP.* Part I. *Modelling design and basic performance characteristics*, J. Appl. Meteorol., 1995, 34, 1739–1761.

[40] ARDAO-BADEJRO J., STAUFFER D.R., *On the relative contribution of the Newtonian relaxation term in a non-hydrostatic mesoscale model used for dynamic analysis*, Proceedings from the 11th American Meteorological Society Conference on "Numerical Weather Prediction, Norfolk", VA, August, 1996.

[41] BARNA M., LAMB B., *Improving ozone modelling in regions of complex terrain using observational nudging in a prognostic meteorological model*, Atmos. Environ., 2000, 34, 4889–4906.

[42] JACOBS H.J. et al., *The use of nested models for air pollution studies: an application of the EURAD model to SANA episode*, J. Appl. Meteorol., 1995, 34, 1301–1319.

[43] PIELKE R.A., ULIASZ M., *Use of meteorological models as input to regional and mesoscale air quality models*, Atmos. Environ., 1998, 32, 1455–1466.

[44] SCHAYES G. et al., *Topographic vorticity mode mesoscale (TVM) model.* Part I. *Formulation*, J. Appl. Meteorol., 1996, 35, 1815–1823.

[45] TANGUAY M. et al., *A semi-implicit semi-lagrangian fully compressible regional forecast model*, Monthly Weather Rev., 1990, 118, 1970–1980.

[46] MARKIEWICZ M., *A review of air pollution dispersion models* (in Polish), scientific publication of Warsaw University of Technology, 1996, 27, 34–67.

METODY WYZNACZANIA DANYCH METEOROLOGICZNYCH UŻYTYCH W MODELACH ROZPRZESTRZENIANIA SIĘ ZANIECZYSZCZEŃ

Modele rozprzestrzeniania się zanieczyszczeń w powietrzu atmosferycznym wymagają wielu danych wejściowych takich jak: dane o emisji, dane meteorologiczne i dane fizjograficzne. Dane meteorologiczne są wyznaczane za pomocą metod tradycyjnych, preprocesorów meteorologicznych, meteorologicznych modeli diagnostycznych i meteorologicznych modeli prognostycznych.

Można zauważyć, że zazwyczaj bardziej skomplikowany model rozprzestrzeniania się zanieczyszczeń wymaga stosowania bardziej zaawansowanych metod wyznaczania pól meteorologicznych. Najczęściej spotykane powiązania między technikami wyznaczania pól meteorologicznych i modelami rozprzestrzeniania się zanieczyszczeń w powietrzu przedstawiono w tabeli 3.