European Topic Centre on Air Quality

REVIEW ON REQUIREMENTS FOR MODELS AND MODEL APPLICATION

by

Frank de Leeuw, Erik Berge, Knut Grønskei and Maria Tombrou

July 1996

This report was prepared under the supervision of G. Kielland, Project Manager,
European Environment Agency

Cover design: Folkmann Design and Promotion
Printing: XXXXXXXXXXXXX

Note

The designations employed and the presentation of material in this publication do not imply the expression of any opinion whatsoever on the part of the European Commission or the European Environment Agency concerning the legal status of any country or territory, and the boundaries shown on maps do not imply official endorsement or acceptance.

ISBN   XXXXXXXXXXXXX

Printed in XXXXXXX on recycled and chlorine-free bleached paper

European Environment Agency
Kongens Nytorv 6
DK - 1050 Copenhagen K
Denmark
Tel: +45 33 36 71 00
Fax: +45 33 36 71 99
E-mail: eea@eea.dk
Homepage:http://www.eea.dk

CONTENTS

1. SUMMARY

Atmospheric transport and photochemical models play an important role in the assessment of air quality. In the European countries models have been and still are widely applied. Next to a differentiation of models in terms of the covered spatial or temporal scale, models can be distinguished to their field of application: regulatory purposes; policy support; assessment of air quality; public information and scientific research. The project MA3 of the EEA Work Programme on harmonisation in the use of models for ambient air quality and pollution dispersion/transport is carried out by the European Topic Centre for Air Quality (ETC-AQ). As a first step in this project, the requirements of models and model applications have been reviewed (sub-project MA3-1).

In this report this review on requirements for models and model application is presented. The review has been carried out along different lines:

1. review of the air quality related chapters in the report "Europe Environment; the Dobríš Assessment": analysis of the role of air quality models in preparation of these chapters;
2. to explore the requirements and needs on a pan-European level, a questionnaire has been sent to all 38 European countries;
3. review of the requirements and needs for models and model application from international organisations.

The results are discussed and recommendations are provided.

2. INTRODUCTION

The primary task of the European Environmental Agency (EEA) is to provide the European Union and its Member States with objective, reliable and comparable information on the environment. Among other activities, this will involve assessing environmental quality and sensitivities and the human-induced pressures on the environment. With respect to air pollution, it is well accepted that assessment of air quality requires the use of both monitoring data and atmospheric models in combination with information on atmospheric emissions. According to the multi-annual work programme 1994-1995 of EEA, the European Topic Centre for Air Quality (ETC-AQ) has to carry out three major projects to review requirements and to develop tools for air quality assessment. The first two projects focus on the general approach to assessment and on the establishment of a European monitoring network and database. In the third project, called MA3, emphasis in on harmonisation in the use of models for ambient air quality and pollution dispersion/transport. As a first step, the requirements of models and model applications have been reviewed (sub-project MA3-1). In combination with the second sub-project (MA3-2, reporting on the state of the art of transport models) this will result in the first version of an information system on atmospheric models including databases and software for validation of models under subproject MA3-3. Further-more, guidance reports for model selection and application are prepared in subproject MA3-4.

In this report the review on requirements for models and model application is presented. The review has been carried out along different lines:

1. review of the air quality related chapters in the report “Europe Environment; the Dobríš Assessment”: analysis of the role of air quality models in preparation of these chapters;
2. to explore the requirements and needs on a pan-European level, a questionnaire has been sent to all 38 European countries;
3. review of the requirements and needs for models and model application from international organisations.

Note that in this report, unless explicitly stated, the term ‘model’ refers to a mathematical procedure which results in an estimation of ambient air quality entities (i.e. concentration, deposition, exceedance). Generally no distinction between process-oriented models (based on the description of physical-chemical process) and statistical models is made. In general, process-oriented models will be able to give a description of cause-effect relationships; statistical models are valuable tools in the diagnose of present and past air quality by means of interpolation or extrapolation of monitoring data.

3. REVIEW OF THE EUROPE'S ENVIRONMENT; THE DOBRÍŠ ASSESSMENT

The Dobríš assessment (EEA, 1995) is the most recent and the most complete report on the state of the pan-European environment. This report is structured in 6 parts:

1. The context; dealing with the scope of the report and the reporting technique
2. The assessment; describing the state of the environment in eight fields
3. Pressures; dealing with seven different fields of pressure which impact the environment
4. Human activity; discussing various types of human activities leading to environmental pressure
5. Problems; a more detailed discussion on 12 major environmental problems
6. Conclusions

Air pollution or more general the atmosphere is mentioned in numerous parts of the report. In many cases the atmosphere forms an essential link in the chain from emissions to effects. However, chapters where, to a large extent, emphasis is on air pollution are Chapter 4, "Air" and various chapters in part 5 Problems (Climate Change, chapter 27; Stratospheric Ozone Depletion, chapter 28; Acidification, chapter 31; Tropospheric ozone and other photochemical oxidants, chapter 32; Urban stress, chapter 37) Other chapters in which air quality plays a (important) role are Chapter 10 (The urban environment), Chapter 11 (Human health), Chapter 14 (Emissions).
In the analysis of model requirements we will follow in this report the chain *pressure - state - impact*. For a further subdivision of "*state*" the lines according to Chapter 4 of the Dobríš report will be followed, that is, according to the spatial scale: urban and local air pollution, regional and transboundary air pollution, and global air pollution.

Pressure

Although it is recognised that information on emission to the atmosphere form essential input to atmospheric models, no models have been used in the Dobríš Assessment either as an independent check on the quality of the current emission estimates nor models have been used for compliance testing of emission control programs. Note that for this type of model exercises a high quality set of concentration data is necessary.

State

Urban and local air pollution
Assessment of urban air pollution in major European cities is largely based on monitoring data. The description of population exposure has been limited to the description of ambient air concentrations in relation to population densities. For a

consistent overview of air quality in large cities, a conceptual framework with five groups of indices has been defined:

- environmental pressure (combination of city population and population density)
- emissions to the atmosphere
- climatological impact: average dispersion (wind speed) and smog forming potential (frequency of adverse dispersion conditions)
- exceedances (the observed concentrations of O_3, SO_2 or TSP relative to their Air Quality Guidelines)
- exposure (percentage of population exposed to concentrations above Air Quality Guidelines)

These indices provide guidance in the interpretation and comparison of urban air quality data in order to obtain some understanding of the relative severity of three type of air pollution situations:

1. winter-type smog, mainly caused by SO_2 and particulates
2. summer-type smog mainly caused by ozone as resulting from emissions of VOC and NO_X
3. high annual average concentration levels (including benzene, benzo(a)pyrene and lead, in addition to SO_2 and particulates).

The Dobríš assessment shows that the indices may be used to explain the differences in air quality from city to city. In their present form the indices provide semi-quantative information, that is, the indices may be used for ranking the cities from the most favourable to the most unfavourable city. For a more quantitative description - that is, in terms of number of exceedances etc. - the ‘indices approach’ could be further developed.

For various cities the contribution of domestic and industrial activities to the urban emissions of the principal air pollutants is know. However, the next step - which is a necessary step for optimising emission control strategies - namely the apportionment of ambient concentrations to these activity groups is not presented.

As a conclusion on urban air pollution it can be stated that in the Dobríš report models are scarcely used in assessment of urban air quality. In the literature a number of case studies on urban air quality modelling can be found (see e.g. Gladstone *et al.*, 1991; Jin and Demerjian, 1993; Ku *et al.,* 1987; Pilinis *et al.,* 1993; Rao *et al.,* 1989). Apparently, these models are not suitable for a comprehensive and consistent review of UAQ in large European cities. Reasons might be that published models are too specific (applicable only for a single city, region or country) and/or too complex, so that input requirements can not be fulfilled for the selected 105 cities or the required computer resources are not available.

For the assessment of air pollution from road traffic several ‘easy-to-use’ models have been published (Eerens *et al.*, 1994; Benson, 1992; Petersen, 1980) which are able to give a overview of the situation in a city (e.g. based on the traffic intensity, hot spots and/or number of kilometre street where guidelines are expected to be exceeded). However, in the Dobríš report no reference to the available models has been made.

As urban air pollution is seen as a prominent environmental problem of concern to Europe, there is a need to collect and evaluate the available modelling instruments and to further develop comprehensive modelling methodologies for diagnoses of urban air quality (including traffic situations) and for applications in scenario studies on emission abatement. A first overview of available local scale models will be presented in a separate report by ETC-AQ (Moussiopoulos *et al.*, 1995). An inventarisation of urban air quality models is currently undertaken by COST-CITAIR (COST-615, Monitoring and monitoring of urban air pollution).

Regional and transboundary air pollution

Pollutants involved in environmental problems on the scale of the European continent have atmospheric lifetimes between half a day to a week. Typical examples for this group of pollutants - the acidifying components (SO_2, NO_x, NH_3), ozone, particulates including aerosol bound contaminants like heavy metals and several organic pollutants- have been discussed in the Dobríš report.

Assessment for acid deposition are largely based on the modelling studies under the UN-ECE CLRTAP (*Convention on Long Range Transboundary Air Pollution).* Within this framework EMEP makes estimates of total acid deposition on a 150x150 km scale. Models with an improved resolution are currently under development. The EMEP model (see Sandnes, 1993; Barrett *et al.*, 1995 and references cited therein) and other acid deposition models (e.g. TREND-model, van Jaarsveld, 1995) have not only been applied for establishing total acid loads but in the Dobríš report also examples of source apportionment are shown.

For photo-oxidants, assessments rely strongly on model calculations, in particularly on basis on the EMEP model (Simpson, 1993) although there are also other operational photo-chemical models (Builtjes and Hulshoff, 1991; Derwent and Jenkins, 1991; de Leeuw and van Rheineck Leyssius, 1991). The coverage of existing monitoring networks (EMEP and EUROTRAC-TOR) is too incomplete (or even absent in several parts of Europe) to make it possible to present ozone maps on the basis of monitoring data. Additional information (to a large extent on urban situations) is available from national monitoring networks reporting within the framework of the EU-Directive on air pollution by ozone, see the ETC-AQ summary on exceedance of ozone threshold values in 1994 (de Leeuw *et al.*, 1995). However, this information is limited to exceedance and simple statistical values. A full data set of ozone measurements which combines the data of international and various national networks could facilitate the assessment of ozone levels over Europe.

As the large scale EMEP calculations (spatial resolution 150x50km) are mainly focused on transboundary budgets, they are not optimal for evaluation of the exposure of the urban population to photo-oxidants due to the interaction with locally emitted VOCs and NO_x.

Concerning tropospheric ozone and other photochemical oxidants, models are not only used to create harmonised AQ maps on the continental scale but also for ranking the VOCs to their ability to produce ozone peak values. Source-oriented model calculations have been used to define and evaluate emission abatement strategies (see e.g. Simpson and Styve, 1992; de Leeuw and van Rheineck Leyssius, 1991).

During winter smog periods the most important pollutants are SO_2 and suspended particulate matter. Several models on continental and national scale are available for the analysis of SO_2 episodes (see, for example, the analysis of the January 1995 episode in Simpson *et al.,* 1987; Lübkert, 1989 and de Leeuw and van Rheineck Leyssius, 1990). However, for aerosol particles model predictions on the time scale of 1h/24h relevant for human health are not available. Aerosol consists of a primary, directly emitted component and a secondary component which is formed in the atmosphere. Most important precursors for secondary aerosol are the acidifying components SO_2, NO_x and NH_3. In acid deposition models the secondary aerosol components are generally accounted for, however, for the primary component there are only one or two models on the continental scale available. For yearly averaged concentrations a first estimate of the large-scale aerosol concentrations (primary + secondary) has been made by means of the TREND model (RIVM, 1992; van Jaarsveld, 1995a). Measuring data on aerosol is hardly reported to international data collection programs. The variety in monitoring strategies and measuring techniques strongly limits the intercomparability of national and local networks. The scarcity of assessment information is in sharp contrast to the fact that exposure to particulate matter is considered to pose the greatest potential burden to human health.

For heavy metals and persistent organic pollutants, first estimates of yearly averaged deposition over Europe are presented in the Dobríš Assessment on the basis of calculations with the TREND-model (van Jaarsveld, 1995b). Modelled depositions and depositions inferred from measurements show relatively large discrepancies; uncertainties in emissions, atmospheric behaviour (particle size distribution, chemical decay rates and exchange with soil and water compartment) and measurements all contributes to these discrepancies.

For the continental scale it can be concluded that there is international consensus on the use of atmospheric transport models in assessment studies on acidification and photo-oxidants in the planetary boundary layer. This consensus is largely due to the on-going well established work in the different bodies under the UN-ECE Convention of Long

Range Transboundary Air Pollution. For the other pollutants there is a need to improve the framework for assessments not only with respect to models but also with respect to emission and air quality monitoring information.

Global air pollution

In the discussions on the changing chemical composition of the global troposphere atmospheric models seem to be well incorporated in assessment studies. In the Dobríš report model results showing the contribution of source regions (Europe) and/or source categories (aircraft) to the present tropospheric levels are presented. For more continental aspects, models are well established assessment tools (*see above*).

In the discussion on stratospheric ozone depletion the Dobríš report presents an excellent example on the combined use of monitoring data and models to reveal causes and consequences of the usage of ozone depleting substances. The concept of ‘Ozone Depletion Potential” has been developed on basis of model calculations and provides now guidance in the discussions on the Montreal protocol and its later amendments. Models have been used to evaluate abatement strategies and proposals for global environmental management.

The growing interest in the greenhouse effect has led to a more intense study of historical and current climatic data. In these studies atmospheric models - either directly when they are used to study atmospheric processes (e.g. the role of clouds) or indirectly, when atmospheric models are coupled with other models (e.g. ocean models) to account for potential feed-back mechanisms - are widely used. Climatic change is one of the areas where models have been used to evaluate abatement scenarios.

Impact

Air quality data, either measured or modelled, is used to calculate the exceedances of air quality guidelines or critical loads. In a second step, effects are estimated based on these exceedances. Examples where the chain *pressure-state-impact* is assessed by linking various types of models were found only on the global scale (stratospheric ozone depletion: estimation of cancer incidents; climatic change: estimates of sea level rise, land-degradation). In acidification research the link between economical aspects and exceedances of critical loads (e.g. RAINS model) is well established. For the other topics procedures to relate air quality parameters to environmental effects have hardly been applied within the Dobríš report.

4. REQUIREMENTS AND NEEDS OF EUROPEAN COUNTRIES: RESULTS FROM THE QUESTIONNAIRE

4.1. Data acquisition

The needs and requirements for models has been reviewed by means of a questionnaire. This questionnaire was sent to:

- the National Focal Points of EEA member states
- some of the National Reference Centres
- to contact persons in 21 European countries which are not a member of EEA

Questionnaires were sent out on 17 February 1995 to the 17 Member states. It was requested to return the questionnaire before 15 March 1995. On 27 March 1995 a reminder was send to persons from whom no response was received. The questionnaire to the non-EEA member states was sent on 28 February 1995 with a request to return it before 24 March 1995. In a later stage no reminder was sent to the non-member states.
A questionnaire has also been sent to the organisation of the 6th Workshop on International Exchange of Data for Smog warning and Air Pollution Information Systems in Europe, 16-17 February 1995, Katowice, Poland.
In total 37 questionnaires were returned. For some countries two or more questionnaires have been returned (Italy returned 9 questionnaires; Austria, Finland, Germany and Greece each returned two questionnaires). From the 17 EEA Member states 14 countries (82%, 26 returned questionnaires) returned the questionnaire; from 11 other countries (a response of 52%; 11 questionnaires) answers have been received. On the results of the questionnaire there has been no further contact with the respondents. It is intended that the results will be discussed during a workshop to be organised by the ETC-AQ in 1996.

The questionnaire is presented in Annex I; a list of persons to whom the questionnaire was originally sent is presented in Annex II.

In the section 4.2 the results of the questionnaire are presented. When quantitative results are presented this is based on information accumulated on a country level, that is, when more than one questionnaire was received from a country, the answers were combined as far as possible. In some situations this led to conflicting answers (*yes* in one questionnaire, *no* in the other).

4.2. Results

One country returned the questionnaire unanswered. Reason for this is that models are presently not used at the ministry of Environment due to a lack of financial support. Perhaps in a later stage someone will be involved with models and model applications.

1 .Question: For which applications did you use or are you planning to use air quality models (see note 1 for explanation):

	PRESENT USE		FUTURE USE	
	yes	no	yes	no
regulatory purposes	21	4	21	2
policy support	19	4	20	2
assessment of air quality	20	3	21	1
public information (e.g. smog warning)	11	11	18	3
scientific research	19	3	17	1

In nearly all countries models are presently used for regulatory purposes, policy support, assessment of air quality and for scientific research. In less countries models are used in providing information to the public; a relative large number of countries even indicated that models are not used for this purpose at all.
In the future the application areas of models will generally not change; only in public information the role of models is expected to grow

2 .Question: Who is using the model results :

	reply
❒ administrators	22
❒ policy makers ❒ national	18
❒ policy makers ❒ local authorities	17
❒ scientists	22
❒ others	7

In each country model results are used by a wide group of persons: administrators, policy makers both on local and national level and scientists. The group of ‘other users’ mainly consists of representatives of industry and/or power generation. In two cases model results are also used by the press.

3. Question: Is this person also performing the model calculations?

	reply
❒ yes	11
❒ no	19

In a majority of cases model calculations are generally made by experts or research institutes. However, in the applications of models for regulatory purposes the calculations are made by private companies, consulting firms or local environmental authorities.

4. Question: Can you provide examples of recent studies in which models have been used (when available please include written material such as reports or publications). For which institute and/or organisation have these studies been performed?
A wide range of model applications, including scientific objectives, has been mentioned here. In the majority of cases applications on the local scale are mentioned:

- the use of model results for regulatory purposes; in 11 questionnaires it was explicitly stated that model results were used in issuing permits or for environmental impact studies for industrial plants or new highways;
- the applications for urban areas was mentioned in at least 10 questionnaires.

Assessment of S- and N-deposition was mentioned in seven questionnaires. The use of models in network design or network optimisation was mentioned in three answers. The application in air quality forecasting or alarm systems is mentioned by four persons. Applications of models on the global scale (e.g. climatic change, ozone layer) are mentioned in two questionnaires.

5. Question: Could you briefly describe (or provide copies of reports which describe) the air quality problem (application field, see question 2) for which model results are used?
Judging the answers presented here, the formulation of this question was confusing. In many cases the answer was similar to or a further elaboration of the answer on the previous question. In the brief discussion presented above, the answers on both questions have been combined.

6. Question: Briefly describe to which extent model results are used in the decision-making process :

	reply
conclusions are exclusively based on model calculations	9
conclusions are based on both model and measuring results	20
models provide only qualitative guidance	4
air quality models are used in a more integrated approach	6

In the process of issuing permits conclusions are exclusively based on model calculations. For the other applications modelling is one of the elements used in a decision making process. Nearly all countries indicate that model and monitoring are both used.
The coupling of air quality models with models describing other parts in the causal chain (pressure-state-impact) seems, according to the answers presented here, not well developed. 6 countries stated a more integrated approach, however, only in three cases a coupling with either a energy planning model, emission modules or effect-modules has been indicated.

7. Question. Specify as far as possible the required model output:

- *type of component modelled:*

	reply
primary components[1]	5
❒ SO_2	22
❒ NO_x	20
❒ CO	16
❒ particles	17
❒ NH_3	12

[1]: primary components not further specified

Models for the primary pollutants SO_2 and NO_x are available in all countries; in most countries also models for CO and particles are operational. Ammonia which plays a role in acidification is less frequently described by using model calculations.

7. Question. Specify as far as possible the required model output:

- *type of component modelled (continued):*

	reply
secondary components:	2[1]
❒ sulphate	12
❒ nitrate	12
Photo-oxidants	2[1]
❒ ozone	15
❒ PAN	6

[1]: secondary component not further specified

For the S- and N-compounds, the secondary components are less frequently modelled than their precursors (which suggests that attention will mostly be focused on concentrations of the primary emitted component). The ammonium aerosol is mentioned only by three countries. Of the photo-oxidants attention is mostly focused on ozone; only 5 countries make use of the output of PAN concentrations.

7. Question. Specify as far as possible the required model output:

- *type of component modelled (continued):*

other applications	reply
❒ toxic	6
❒ odour	9
❒ accidental releases	8

Model calculations for toxic substances (e.g. heavy metals, organohalogens) are carried out in 6 countries. Accidental releases (radioactive material, Cl_2 , NH_3) are modelled in 9 countries; additionally in at least one country models are applied for controlled spills of CO_2 or H_2S. In 8 countries the desired model output includes information on odorous components. One respondent admits that this might be beyond the scope of the models as the models used at present are not very suitable for handling of concentration fluctuations.
Other components included in the desired model output are organic compounds/VOC (mentioned in 4 questionnaires), H_2S and trace elements which are both mentioned in one questionnaire.
In one questionnaire noise has been indicated as desired output; this, however, is beyond the scope of the air pollution models discussed here.

The response to the questionnaire clearly indicated that models should predict both concentrations and depositions although concentrations are indicated as desired output in slightly more cases.

7. Question. Specify as far as possible the required model output (continued):

- *required spatial scale and spatial resolution*:

	reply
❒ direct surroundings of single (point) sources	21
❒ direct surroundings of line sources (traffic)	18
❒ local scale, multiple sources	21
❒ special situations, e.g. urban conditions	16
❒ (sub) national scale	15
❒ (sub) European scale	10

In agreement with the application areas of the models, nearly all respondents indicated here that they need models on the local and urban scale. For these small scale applications, the requirements on the spatial resolution ranges from 50m to 1000m.. In a relatively small number of cases the required model area is on the European or global scale (indicated in 11 questionnaires, 10 countries). For applications on the national or European scale, the requested spatial resolution varies from 10x20km to 150x150km.

7. Question. Specify as far as possible the required model output (continued):

- *Required time averaging and time resolution :*

	reply
❒ short term/episode	18
❒ long-term	17
❒ accidental releases	13
❒ on-line forecasting (smog warning)	9
❒ hourly averaged	16
❒ yearly averaged	20
❒ statistical values	17

Based on the time averaging and time resolution two types of models are required by nearly all countries:
1. short-term models calculating hourly averages concentrations;
2. long-term models calculating yearly averaged concentrations and statistical values (50-99 percentiles, number of exceedances etc.).

7. Question: Specify as far as possible the required model output (continued):
Has the required model accuracy been specified?
In the majority of countries model accuracy has not been specified (no: 19 countries; yes: 6 countries).
However, the countries which did specify their model accuracy gave only brief descriptions in very general terms, such as: ‘by statistical model evaluation’, ‘validation against measurements’; one country requires for some of its models a 30% accuracy with at a 70% confidence level.

7. Question: Specify as far as possible the required model output (continued):
Are there any further requirements regarding models or model application?
Next to new application fields of models (forecasting of PM10 concentrations, models for the urban environment including heat island effects, models for point sources in complex terrain) the need for model evaluation procedures was mentioned.

7. Question (continued): Please specify the models which have actually been applied (names, references, etc.):
This question resulted in a long list of acronyms of all kinds of models. For local scale applications (around point sources) various gaussian-type models are in use. For national and European scale applications, a large variety of model types (Eulerian/Lagrangian, with simple/complex atmospheric chemistry, long/short term averaging etc.) is mentioned here. The information gathered will serve as input for the proceeding project on modelling (project MA3-2, Report on the State of the Art, needs and trends). The answers on this question strongly indicate that each country has been developing (or is developing) its own models. Generally, a specific model is mentioned in one questionnaire only; in addition it

was frequently indicated that the models have been developed 'in-house'. As an exception, some US-EPA models are mentioned in two or more questionnaires.

8. Question:. Do you expect that your requirements regarding models and model applications as described in questions 5 - 7 will change in the near future (1-3 years)?
11 countries indicated that they expected that future requirements will not differ from the present situation. A change in requirements is anticipated in 14 countries. Their answers are discussed below, see question 9.

9. Question on future requirements:
- Could you briefly describe the air quality problem (application field, see question 2) for which model results will be used in the future (1-3 years)?
Models for urban air quality problems including the modelling of pollution from traffic (i.e. in street canyons, in or close to parking garages) has been indicated as future requirement. The need for chemical models for modelling of concentrations of ozone and other photochemical compounds is mentioned by several countries. A more integrated model approach (within 'atmospheric' problems - coupling of N- and S-cycles and deposition to ozone problem and VOC reduction - but also a direct coupling with soil quality models or socio-economical models) is necessary. The need for visibility models is expressed twice.
One respondent expressed the need to model exposures to air pollutants but no further specifications (required spatial/temporal resolution, compounds, requirements on the modelling of in-door air quality, etc.) has been given.
The specifications on the required model output show some minor changes:

- For the modelled component there will be an extension with heavy metals and POPs; noise and odour are both mentioned once as required component;
- required spatial scale and spatial resolution will not be different from the present situation;
- the requirements on time averaging and time resolution show a slight increase in interest for on-line modelling (smog forecasting).

With respect to the documentation of the models it was mentioned that this should at least consists of a user manual, short technical description and the results of sensitivity and validation tests.

10. Question: It is planned to prepare a catalogue of operational air quality models. For this model inventory a second questionnaire with detailed questions on model specifications and characteristics will be sent out mid 1995 to persons who are actually involved in model development. Please indicate below persons or institutions who should be contacted.
Per questionnaire 0 to 6 names of institutes or persons actually involved in model development were indicated. Although it was planned to use this list of contact persons in further work under this project MA3, a questionnaire has not yet been sent.

11. Question:. We would be grateful for any further comments on requirements regarding models and model applications

11 persons have made use of this invitation for further comment. In 8 of these answers it was stated that there is an urgent need for harmonisation of atmospheric dispersion models at a European level; suggestions are made to develop data bases with reference data for model validation and to start intercomparison studies of models and/or model subroutines. Intercomparison should be made on all relevant time and spatial scales (local <=> LRT; short term <=> long term). Several respondents suggested to continue the series of workshops started in 1991 by the ad-hoc initiative[1] on harmonisation and validation of regulatory short range models.

[1] Air quality model developers and users from Europe and the USA decided in 1991 to organise a series of workshops to investigate the various aspects of atmospheric modelling for regulatory purposes with emphasis on model requirements (Risø, Denmark, 1992), on model intercomparison and validation (Manno, Switzerland, 1993) and on operational models presently used in Europe (Mol, Belgium, 1994). After the third workshop, it became clear that the regulatory models currently used in the different countries of the EU yield results that, for the same input, differ almost an order of magnitude. The need for harmonisation in the use of regulatory models has been demonstrated. The fourth workshop (Oostende, Belgium, 1996) will focus on operational local impact models for simple and complex terrain with emphasis on their inter-comparison, validation and practical applications, on the harmonisation of the pre-processing of the meteorological data required in these models and on micro-scale dispersion in cities. An important activity within the *ad-hoc initiative* has been the production of a so-called *model evaluation kit*. This kit is a collection of three experimental data set accompanied by software for model evaluation. It is a practical tool, meant to serve as a common frame of reference for modellers.

5. REQUIREMENTS ON AIR POLLUTION MODELS FROM INTERNATIONAL ORGANISATIONS

The control of air pollution at local, regional and global scale is the subject of several regulations, directives and conventions both within the European Union and in international organisations. In summarising the requirements for models and model applications from international organisations we will focus in this report on models for the assessment of ground level pollution in Europe. Discussions on global scale models are covered in various international organisations such as the Intergovernmental Panel on Climate Change (IPCC), the World Climate Research Programme (WRCP), the International Geosphere-Biosphere Programme (IGBP). In addition to the review of requirements on models based on the EU Directives and Decisions, the requirements of the UN-ECE Convention of Long Range Transport of Air Pollution and the marine conventions will be discussed. Requirements for models resulting from bi- or trilateral agreements between European countries are not included in this summary.

For protection of marine environments three organisations, HELCOM, OSPAR and MEDPOL are active within Europe. For all three organisations assessments of total pollution loads to the marine systems are made. Atmospheric input is only one of the pathways by which pollution enters the system; the relative importance of atmospheric deposition depends on the component in question and on the geographical location. Based on information obtained from the marine organisations, their requirements for atmospheric models/model applications are summarised below.

Requirements for models in EU Directives and Decisions

Relevant Directives and Decisions are:

- Council Directive 80/779/EEC, amended by Directive 89/427/EEC on air quality limit values for sulphur dioxide and suspended particulates
- Council Directive 82/884/EEC on limit values for lead
- Council Directive 85/203/EEC on air quality standards for nitrogen dioxide
- Council Directive 92/72/EEC on air pollution by ozone
- the proposed Council Directive on Ambient Air Quality Assessment and Management (Framework Directive on Ambient Air Quality, FWD).

According to the directives on SO_2, particulates, lead, NO_2 and ozone the Member States shall inform the Commission on exceedances of air quality limit values. The information on exceedances is based on monitoring information only; the (possible) application of air pollution models in the assessment is not mentioned. However, in the interpretation of observed exceedances and, moreover, in the development of solutions to prevent further exceedances, models, in combination with monitoring data and emission inventories, will play an important role.

According to the proposed Framework Directive “assessment of air quality means any method used to measure, calculate, predict or estimate the level of a pollutant in the ambient air” and therewith air pollution models are acknowledged as assessment tools. Criteria and techniques for the spatial resolution of modelling and methods of objective evaluation and reference techniques for modelling have to be established in respect of each pollutant according to the size of agglomerations or to the levels of pollutants in the zones assessed.

The following assessment technique, depending on the difference between limit values and representative actual levels, is proposed in Article 6:

1. In zones where measurements are mandatory[2] “the expected measures may be completed by the use of modelling and other techniques to provide adequate information on the quality of ambient air.
2. For the assessment of ambient air quality, a combination of measurement and modelling techniques may be used when representative levels are below a level to be determined in the legislation outlined in Article 4.1.
3. When the levels are below a threshold to be determined in the legislation outlined in Article 4.1, the sole use of modelling or objective estimation techniques for assessing levels shall be possible”.

Discussions on the requirements on air quality modelling for the purposes of reporting compliance with the FWD are now taken place in the working groups for daughter directives for SO_2, NO_2, particulates and lead.

[2] see the Framework Directive for a precise definition of these zones; in general terms, mea-surement is mandatory in zones in which levels are above the level referred to under point 2.

UN-ECE Convention of Long Range Transboundary Air Pollution

The modelling efforts under UN-ECE CLRTAP are carried out in EMEP and in particular at the two Meteorological Synthesising Centres in Oslo and Moscow. Objectives of the model efforts are primarily to monitor and evaluate the long range transboundary fluxes of air pollution and the deposition to ecosystems and to support the decision makers in their process of developing protocols on reduction of emissions to the European atmosphere. LRTAP-models have been developed for this purpose in order to quantify the fluxes of acidifying components and photooxidants. The routine EMEP models make estimates of deposition and concentrations on a scale of 150x150 km. Models with an improved resolution are currently under development to strengthen the support of assessments. Models to cover HM's and POP's are under development. The main requirements for the CLRTAP are:

- Provision of emission data as national totals, future projections and gridded distribution from all European countries as a major input to the model calculations. In the future a closer harmonisation and collaboration between UN-ECE and EEA on the reporting, storing and verification of the emission data is foreseen including closer contacts with national experts.
- Model development and improvement of transport models, in support of the assessments carried out under the Convention. Interactions mainly on a European level with Universities, National Centres (RIVM, FMI, IVL etc.) and scientific programmes/European programmes such as EEA, EUROTRAC, HELCOM, OSPARCOM, WHO-ECEH etc. are required.
- Increased number of measurements of photooxidants, Heavy metals and Persistent Organic Pollutants. The acidifying components are reasonably well covered in the monitoring network under UN-ECE. Common databases with measurements and model calculations from different models would facilitate the work on model evaluation. Co-ordination with EEA and the main modelling communities of LRTAP in Europe is desirable.

HELCOM

The Helsinki Commission (HELCOM) carries out the Helsinki convention on the protection of the marine environment of the Baltic Sea Areas. HELCOM will prevent and abate pollution, will protect and will improve the marine environment of the Baltic Sea area without causing an increase of pollution outside this area. The priority substances taken into account within the framework of HELCOM are summarised in Table 5.1.

Surveillance and assessment studies have been carried out to provide data on the emissions, fluxes and deposition of pollution over the Baltic Sea. Data on transport of pollution through the atmosphere include measurements of emissions, air concentrations and depositions. Few measurements are carried out over the sea and therefore the assessment studies have to rely on the results of model calculations combined with measurements.

In addition to a description of wind, temperature and dispersion, the distributions of precipitation and the structure of the atmospheric surface layers over the Baltic Sea are important for the description of wet and dry deposition.

Table 5.1. List of priority substances taken into account for assessment of atmospheric within the framework of HELCOM and OSPAR.

Heavy metals	other inorganic pollutants	Organic Pollutants
Hg	Ammonia	HCH
Cd	Nitrogen oxides[1]	pentachlorophenol
Cu		hexachlorobenzene
Zn		carbontetrachloride
Pb		trichloroethylene
As		tetrachloroethylene
Cr		trichlorobenzene
Ni		trichloroethane
		dioxins/furans[2]
		PAHs
		xylenes [1]

[1] in HELCOM-framework only
[2] in OSPAR-framework only

Models have been developed for the deposition of reduced and oxidised nitrogen and for trace metals (HELCOM, 1991); models for the organic pollutants are generally not available. The quality assurance of the estimates includes a quality control of measurements and various model evaluations. Control and specification of the accuracy of the deposition estimates may be further developed.
Recently an agreement on co-operation on the preparation of air emission inventories, the management of atmospheric monitoring and the modelling of air pollution in the Baltic region has been established between EMEP and HELCOM.

OSPARCOM

Within the framework of the Oslo and Paris Commissions for the prevention of marine pollution in the North East Atlantic (OSPAR) and with a view to the entry into force of the Convention for the Protection of the Marine Environment of the North East Atlantic, 1992, one of the tasks of the working group on Inputs to the Marine Environment (INPUT) is to arrange for the monitoring of, or collection of information on, input of substances from all possible sources to the marine environment. In order to contribute to the preparation of Quality Status Reports for the regions of the maritime area by mid 1999 and for the whole maritime area by the year 2000 (see Figure 1), INPUT shall evaluate this information with regard to geographical distribution, temporal trends and the proportion which is of anthropogenic origin. As regards atmospheric input, assessments will be based on the measurements made at coastal stations under

OSPAR's Comprehensive Atmospheric Monitoring Programme (CAMP) and on modelling activities. Long-range transport models have been used to estimate atmospheric inputs to the North Sea for the years 1987 to 1992 (Oslo and Paris Commissions, 1994).

In close co-operation with other international organisations, OSPAR's future modelling activities will focus, *inter alia*, on the provision of:

- reliable estimates for total atmospheric deposition to the whole maritime area of the substances listed in Table 5.1.
- data for the assessment of trends in atmospheric deposition and to identify source sectors for which priority actions should be taken; and
- data for the assessment of the effectiveness of measures to control atmospheric pollutants.

MEDPOL

MEDPOL, the co-ordinated Mediterranean Research and Monitoring programme is the assessment (scientific/technical) component of the Mediterranean Action Plan (MAP).

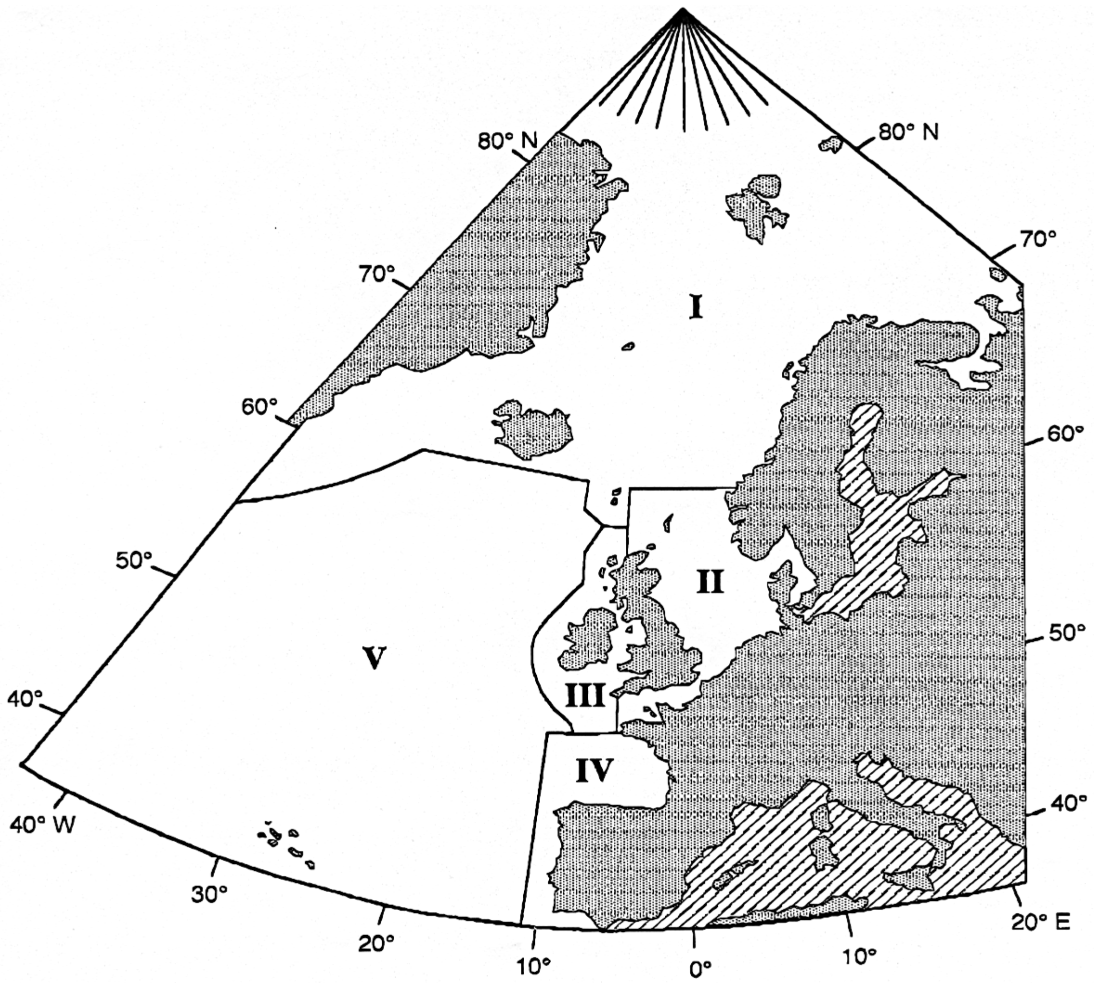

Figure 1. Maritime Area of the Oslo and Paris Conventions. The area is subdivided in the regions I, Arctic Waters; II, Greater North Sea; III, the Celtic Seas; IV, Bay of Biscay and Iberian Coasts; V, Wider Atlantic.

Other components within MAP are a management component (integrated planning of the development and management of the resources of the Mediterranean Basin) and a legal component (framework convention and related protocols with their technical annexes for the protection of the Mediterranean environment. In MAP all coastal states in Southern Europe, North Africa and the Middle East participate along with the European Union which is also a party to the convention.

The MEDPOL programme comprises i.e. the monitoring of and research on pollutants affecting the Mediterranean marine environment but MEDPOL also take into account factors needed for the understanding of the relationship between socio-economic development of the region and the pollution of the Mediterranean Sea. The World Meteorological Organisation (WMO) is responsible for the activities related to atmospheric transport of pollutants. Within the framework of MEDPOL several research groups have been applying atmospheric models. One important study concerns the modelling of total deposition of N- and S-compounds and several heavy metals to the Mediterranean Sea and its sub-regions (Dedkova *et al.*, 1992). For future model applications requirements on model output are monthly and annual averaged depositions (wet + dry) and concentrations of Pb, Cd, Zn, As, Hg, dust and some POPs. Models for optimal cost-benefit abatement strategies for emission reductions in the region and this for reduction of the atmospheric load are needed. Models for testing the reported emissions and for providing information on compliance with adopted regional measures concerning reduction of airborne pollution should be applied.

6. DISCUSSION & CONCLUSIONS

In air pollution assessments information on all parts of the cause-effect chain have to be collected. A physical/chemical description of ambient air has to be presented in such a way that it can be compared with effect threshold values and the relation between this ‘effect quantity’ and the atmospheric emissions from sources (e.g. countries, regions, economical sectors) should be quantified. Only when all three elements, (threshold or critical values, ambient parameters and emissions) are available an optimal strategy to control and abate the sources of pollution in order to improve air quality, can be developed. Three types of instruments are used in assessment studies: emission inventories, atmospheric transport models and air quality measuring programmes. As air pollution models bridge the information of emission inventories and air quality measuring results a close co-operation between the Topic Centres on Air Emissions and Air Quality is needed.

Air quality monitoring may be defined as the systematic collection of information from measurements or other means to determine the levels and the time evolution of quantities relevant for air quality. Such quantities are air concentrations, fluxes of air pollutants to land or water surface and the exposure to air pollution of human beings, materials and ecosystems.

The aim of air quality monitoring is to get an estimate of the quantities required (concentrations, deposition fluxes, or exposure) with a specified representativeness in time and space and a specified accuracy. Spatial scales may range from the global scale to the very local scale (e.g. street level, direct surroundings of a chimney); time scale may range from minutes (estimation of peak concentrations) up to decades (estimation of trends).

Determining the relevant quantities requires systematic information obtained by a pre-defined information collection strategy, derived from the specified requirements. Interpretation and evaluation of the data is necessary to evaluate the required quantities and to verify that these requirements are met.

Although measurements form an important aspect of monitoring, measurements alone are rarely sufficient to arrive at the best possible description of the desired concentration or deposition fields. Models are often used to interpolate and generalise measured information or to generate best estimates in situations where measurements are lacking or cannot be made. Models are necessary if the relative impact of various source (categories) has to be estimated.

Atmospheric models are, broadly speaking, any mathematical procedure which results in an estimation of ambient air quality entities (i.e. concentrations, deposition, exceedances). In general term a distinction between process-oriented models and statistical models can be made. Process oriented models are based on the description of physical chemical processes: starting with emissions, atmospheric advection and dispersion, chemical transformation and deposition is calculated. This type of models is able to give a description of cause-effect relations. Statistical models are valuable tools in the diagnose of present air quality by means of interpolation and extrapolation of measuring data.

Although atmospheric models are indispensable in air quality assessment studies, their limitations should always be taken into account. Once a model has been developed the further application of the model will be relatively cheap, however, collecting the necessary input data might be cumbersome. Models can be used for estimating past, present and future air quality provided that information on emissions is available. The contribution of source regions, economical sectors etc. to the ambient levels can easily been deduced from model calculations. Uncertainties in model results may be large; uncertainties are both introduced by the model concept and by the input parameters (emission data, meteorology). The representativeness of model results may be limited: in all current models a spatial and temporal averaging is introduced which disables a direct comparison with measurements at one location at a given moment.

Note that also measurement data has its own advantages and drawbacks. Measurements may give a direct observation of the effect entities although measurements of some specific entities such as total deposition fluxes may be extremely expensive. Measurements are generally assumed to give the ground truth, however, intercomparison studies suggest that this statement is sometimes questionable (Slanina *et al.,* 1990; Ross and Areskoug, 1993). Information on trends in concentrations can be obtained from long-term measurements. A serious problem in the interpretation of monitoring data is that the representativeness of measurements at one location may be limited, for example concentrations measured in a busy street are not representative for the concentrations in the more residential area of a city. Large uncertainties may be introduced if measured data are extrapolated or interpolated to large areas. In view of this discussion it will be clear that by combining both models and measurements the assessment of air quality can be improved.

A wide range of different models are published in scientific papers and even a larger number of unpublished models and special model versions exists. The good response to the questionnaire might indicate that the use of models as a tool in air quality assessments is well accepted by large groups of users (administrators and policy makers).

The answers to the questionnaire indicate that regulatory models on urban/local scale are in use in most European countries. More policy oriented models on the continental or global scale are hardly mentioned by the respondents. This, however, does not implies that their is no need for this type of models: in the preparation of the Dobříš Assessment the results of global and continental models have been used frequently. On the continental scale, EMEP clearly focuses on transboundary air pollution (acidification, photooxidants) and has developed a program for monitoring and assessment in this field. On the global scale, international organisations such as IPCC, WRCP play a similar role in the assessment of global air pollution.(climate change, ozone depletion). By sending the questionnaire to NFPs and NRCs, it might be group of users of global/continental models is less well addressed as most of the EU legislation on air quality applies on the local/urban scale.

Models can be distinguished on many grounds: e.g. the underlying physical concepts, the temporal and spatial scale, type of component. Here we define four groups of application area and briefly discuss the requirements.

1. Regulatory purposes

In nearly all European countries models are presently in use for regulatory purposes. Model results are used in issuing emission permits (usually for single sources) or for environmental impact studies for, for example, industrial plants and new highways. In general terms, models in this application area have to provide spatial distribution of high episodic concentrations and of long-term averaged concentrations for comparison with air quality guidelines. A wide range of pollutants is modelled (e.g. SO2, NO2 but also toxic substances like heavy metals and organohalogens). In some situations the desired model output should include information on odorous components. It is disputable that this might be beyond the scope of most of the models as the models used at present are not very suitable for handling of concentration fluctuations.

In the framework of a European *ad hoc* initiative on *Harmonisation within Atmospheric Dispersion Modelling for Regulatory Purposes* standardised methods (e.g. tools for model evaluation: reference data set, software and protocols for model evaluation) are being developed. Surprisingly however, according to results of the questionnaire, in the majority of countries model the required accuracy has not been specified. An European effort to establish the reliability of models, including the development of a tool kit for model validation and uncertainty analysis, is recommended.

According to the EU Air Quality Directives the area where threshold values are approached or exceeded has to be assessed and reported by the Member States. Threshold values both for protection of human health and for protection of ecosystem are defined for primary and secondary pollutants. Although in many situations only measuring data is used for specifying the exceedance area, models - including statistical methods for interpolation of data - could significantly improve the description. In the "old" EU Air Quality Directives on SO_2, TSP, NO_2, lead and ozone models are not mentioned as assessment tool. In the "new" Framework Directive and the related

Daughter Directives concerning SO_2, TSP, NO_2 which are now being elaborated, modelling techniques may be used for assessment of the air quality in zone with “low” pollutant levels and for delimitation of areas for which the measured values and exceedances of limit values or alert thresholds at certain sites are representative. Discussions on requirements for models for this type of applications are not yet finalised.

2. Policy support and assessment studies
As discussed above, in air quality assessment studies models play an important role next to emission inventories and measuring programmes. Frequently, for policy support the effect of abatement measures has to be predicted by the models; this may require that the model also gives reliable results under pollution conditions which differ strongly from the present situation.

Use of atmospheric models in combination with models for other compartments (e.g. soil, water but also emission modules) in order to obtain a more integrated approach is becoming more and more important. For practical reasons this might imply that more simplified models without losing essential information have to be developed; an example of this type of *meta-models* is the source-receptor approach implemented in the RAINS model which is based on the much more complex EMEP model.

As is indicated by the answers to the questionnaire, the future specifications on the required model output show some minor changes in the modelled components when compared to the present situation; there is a need for extension of the models to include heavy metals and POPs. Modelling of visibility and particulate concentrations (PM10) are new topics for which some countries expressed their need.

The marine conventions (HELCOM, MEDPOL, OSPAR) expressed their need for assessment of atmospheric deposition of nutrients and toxic or hazardous compounds. Co-operation between the marine conventions and the Topic Centres on coastal zones and marine environment and on air quality is recommended.

The models which are presently available seem to be adequate to cover the present and future needs as indicated by the respondents. However, there are some obvious gaps in model application areas (e.g. modelling of indoor air quality for exposure assessment) and some topics are not well covered by present models (e.g. odour).

With respect to the documentation of the models, there were no well defined requirements given in answer to the MA3-1 questionnaire but, according to answers of several respondents, there is a clear need for improvement of model documentation. In the documentation the following topics could be included:

- specification of the scientific concepts applied in the model

- the limitations of the model (area of application)
- the results of validation procedure; the results of sensitivity analysis
- a discussion on the expected accuracy of the modelled quantities
- description of input and output; description of computer hardware requirements
- examples of model applications.

3. Public information

In public information the role of models is expected to grow. Requirements for models for public information parallel to a large extent the requirements for policy support as far as assessment studies are concerned. For on-line information to the public on air quality and the possible occurrence of smog episodes, air quality forecast models are needed. In a series of workshops it has been attempted to harmonise these on-line forecasting models (see the minutes of the 5th Workshop on International Exchange of data for smog warning and Air Pollution Information Systems in Europe, Luxembourg, 21-22 April 1994). Although the workshops resulted in an exchanges of views and know-how and in an on-line system of reciprocal exchange of smog information between a number of countries, no harmonisation in forecast models has been specified.

4. Scientific research

Objectives for scientific models are the description of dynamical and photochemical processes relevant for air pollutants. In many cases models of this type are too complex or their requirement on manpower and computer power are too high for application in the other three fields. These models are valuable for evaluation and identification of limitations and gaps in the more policy oriented models and for further development of the policy supporting models. In this report the requirements on scientific research models will not be further discussed as there are other, more appropriate fora for that.

7. REFERENCES

Barrett, K., Seland, O., Foss, A., Mylona S., Sandnes, H., Styve, H. and Tarrason. L. 1995. European Transboundary Acidifying Air Pollution. Ten years calculated fields and budgets to the end of the first sulphur protocol. EMEP/MSC-W Report 1/95. The Norwegian Meteorological Institute, Oslo, Norway.

Benson P.E. (1992) A review of the development and application of the CALINE 3 and 4 models. *Atmospheric Environment* **26B**, 379-390.

Builtjes P.J.H. and Hulshoff J. (1991) The LOTOS project. Long period modelling of photochemical oxidants in Europe using the LOTOS model. Report P91/021, TNO, Delft.

Dedkova I., Erdman L. Galperin M. Grigoryan M. Sophiev M. (1992) Assessment of the airborne sulphur and nitrogen pollution of the Mediterranean and Black Seas from European countries 1987-1991.Report 4/92, EMEP- MSC-East , Moscow.

De Leeuw F.A.A.M. and Van Rheineck Leyssius H.J. (1991) Calculation of long-term averaged and episodic oxidant concentrations for the Netherlands. *Atmospheric Environment*, **25A,** 1809-1818.

De Leeuw F.A.A.M. and Van Rheineck Leyssius H.J. (1990) Modelling study of SO_x and NO_x transport during the January 1985 smog episode. *Water Air and Soil Pollut.* **51,** 357-371.

De Leeuw F., Sluyter R., van Zantvoort E., and Larssen S. (1995) Exceedances of ozone threshold values in the European Community in 1994. Summary based on the information reported in the framework of the Council Directive 92/72/EEC on air pollution by ozone. ETC-AQ, Bilthoven, the Netherlands.

Derwent R.G. and Jenkins M.E. (1991) Hydrocarbons and the long-range transport of ozone and PAN across Europe. *Atmospheric Environment*, **25A**, 1661-1678.

Eerens H.C., Sliggers C.J. van den Hout K.D. (1993) The CAR model: the Dutch method to determine city street air quality *Atmospheric Environment* **27B,** 389-399.

European Environment Agency Task Force (1995) Europe’s Environment. The Dobríš Assessment (Stanners D. and Bourdeau P., editors) European Environmental Agency, Copenhagen.

Gladstone, K.P.; H. Niki; P.B. Shepson; J.W. Bottenheim; H.I. Schiff; H.S. Sandhu (1991); Photochemical oxidant concentrations in two Canadian prairie cities: model evaluation. *Atmospheric Environment*, **25B**, 243-254.

HELCOM (1991) Airborne pollution load to the Baltic Sea Environment. Proc. No. 39.

Jin, S.; K. Demerjian (1993); A photochemical box model for urban air quality study. *Atmospheric Environment,* **27B**, 371-387.

Ku, J.Y.; S.T. Rao; K.S. Rao (1987a) Numerical simulation of air pollution in urban areas: model development. *Atmospheric Environment*, **21**, 201-212.

Ku, J.Y.; S.T. Rao; K.S. Rao (1987b) Numerical simulation of air pollution in urban areas: model performance. *Atmospheric Environment*, **21**, 213-232.

Lübkert B. (1989) Characteristics of the mid-January 1985 SO_2 smog episode in Central Europe. Report from an International workshop. *Atmospheric Environment*, **23,** 611-623.

Moussiopoulos N., Berge E., Bøhler T., de Leeuw F., and Grønskei K.-N. (1995) Models for ambient air quality and pollutant dispersion/transformation; State of the art - needs and Trends. Report MA3, ETC-AQ.

Oslo and Paris Commissions (1994) Calculation of atmospheric inputs of contaminants to the North Sea, 1987-1992. Oslo and Paris Commissions, London.

Petersen W.B. (1980) User's guide for HIGHWAY-2. A highway air pollution model, 3-17. EPA-600/8-80-018. Environmental Science Research Laboratory, Office of Research and development U.S. Environmental Protection Agency, Research Triangle Park, North Carolina 27711.

Pilinis, C., P. Kassomenos P., Kallos G. (1993); Modelling of photochemical pollution in Athens, Greece. Application of the RAMS-CALGRID modelling system. Atmospheric Environment, Vol. 27B, No. 4, pp. 353-370.

Rao, K.S.; J.Y. Ku; S.T. Rao (1989) A comparison study of three urban air pollution models. *Atmospheric Environment,* **23,** 793-801.

RIVM (1992) The environment in Europe: a global perspective. Report 481505001, RIVM, Bilthoven.

Ross H.B. and H. Areskoug (1993) Intercomparison of collection methods for the determination of trace metals deposition to European marginal seas. ITM-report 14, Institute of Applied

Sandnes H. (1993) Calculated budgets for airborne acidifying components in Europe, 1985, 1987, 1988, 1989, 1990, 1991 and 1992. EMEP/MSC-W Report 1/93. Norwegian Meteorological Institute, Oslo.

Simpson D. , Davies S., Gooriah B.D. McInnes G. (1987) Pollution levels in the United Kingdom during 14-22 January 1985. *Atmospheric Environment,* **21,** 2495-2503.

Simpson D. and Styve H. (1992) The effect of the VOC protocol on ozone concentrations in Europe. EMEP-MSC-W note 4/92. Norwegian Meteorological Institute, Oslo.

Simpson D. (1993) Photochemical model calculations over Europe for two extended summer periods: 1985 and 1989. Model results and comparison with observations. *Atmospheric Environment,* **27A,** 921-943.

Slanina J., J.J. Mols and J.H. Baard (1990) The influence of outliers on results of wet deposition measurements as a function of measurement strategy. *Atmospheric Environment,* **24A**, 1843-1860.

Van Jaarsveld J.A. (1995a) Modelling the long-term atmospheric behaviour of pollutants on various spatial scales. Thesis, Utrecht.

Van Jaarsveld (1995b) Atmospheric deposition of cadmium, copper, lead, benzo(a)pyrene and lindane over Europe and its surrounding marine areas. Background report to the ESQUAD study. Report 222401002, RIVM, Bilthoven, the Netherlands.

Yamertino R.J. and Wiegand G. (1986) Development and evaluation of simple models for the flow, turbulence and pollutant concentration fields within an urban street canyon. *Atmospheric Environment* **20,** 2137-2156.

ANNEX I : QUESTIONNAIRE

REVIEW ON REQUIREMENTS FOR MODELS AND MODEL APPLICATION

According to the Annual Work Programme Mid 1994-1995 of the European Environmental Agency (EEA) the European Topic Centre for Air Quality is carrying out a project on harmonisation in the use of models for ambient air quality and pollution dispersion/transport (project MA-3). This project will be carried out in collaboration with the ad-hoc initiative on harmonisation and validation of regulatory short range models, and similar European initiatives for other models. As part of this project the requirements for models and model applications in all European countries in particular in the EU and its member states is reviewed (project MA3-1).

You could be of great help to us by answering this questionnaire and returning it by **15 MARCH 1995** at the latest to the address indicated below. Note that this questionnaire will be used for reviewing the *requirements for models and model applications.* **Therefore, a person who actually uses the model results rather than a person who is involved in model development is invited to answer the questionnaire.**

It might be that not all questions fall under your responsibility or that more organisations/institutes have responsibilities for the application of atmospheric models. We would appreciate you also contacting these persons.

Please note that this questionnaire is limited to models which are used in policy making, for regulatory purposes and in the assessment of air quality. Where relevant you are invited to give a double set of answers, one describing the present situation, the second referring to requirements in the (near) future.

1. person who answered this questionnaire

Name	
Function	
Organisation	
Address	
Telephone	
Fax	
e-mail	

Return address: Frank de Leeuw, RIVM, P.O.Box 1, 3720 BA Bilthoven, the Netherlands,
tel +31-30-742806, fax +31-30-287531, e-mail frank@rivm.nl

2. For which applications did you use or are you planning to use air quality models (see note 1 for explanation):

	present use	future use
- regulatory purposes	yes / no	yes / no
- policy support	yes / no	yes / no
- assessment of air quality	yes / no	yes / no
- public information (e.g. smog warning)	yes / no	yes / no
- scientific research	yes / no	yes / no

- other, namely ....

3a. Who is using the model results :

❒ administrators

❒ policy makers ❒ national

❒ local authorities

❒ scientists

❒ others, namely ....

3b. Is this person also performing the model calculations?

❒ yes

❒ no,

model calculations are generally done by

....

....

4. Can you provide examples of recent studies in which models have been used (when available please include written material such as reports or publications). For which institute/organisation have these studies been performed?

In the following questions more information on model requirements for the various application fields is asked for. Please answer the questions for each of the application fields.

5. Could you briefly describe (or provide copies of reports which describe) the air quality problem (application field, see question 2) for which model results are used?

6. Briefly describe to which extent model results are used in the decision-making process :

❐ conclusions are exclusively based on model calculations

❐ conclusions are based on both model and measuring results

❐ models provide only qualitative guidance

❐ air quality models are used in a more integrated approach, that is they are coupled with others models, for example with economic process models or with effect models. Please specify these models ....

....

....

❐ other: ....

....

....

7. Specify as far as possible the required model output:

- type of component modelled:
  - ❐ primary components: ❐ SO_2 ❐ NO_x ❐ CO ❐ particles ❐ NH_3 ❐ others:.............
  - ❐ secondary components: ❐ sulphate ❐ nitrate ❐ others: ....
  - ❐ photo oxidants: ❐ O_3 ❐ PAN ❐ others: ....
  - ❐ toxic/hazardous (please specify): ....
  - ❐ odour
  - ❐ accidental releases; modelled component:..
  - ❐ other: ....

- modelled quantity: ❐ concentration
  ❐ deposition

- required spatial scale and spatial resolution:
  - ❐ direct surroundings of single (point) sources
  - ❐ direct surroundings of line sources (traffic)
  - ❐ local scale, multiple sources
  - ❐ special situations, e.g. urban conditions
  - ❐ (sub) national scale
  - ❐ (sub) European scale
  - ❐ spatial density of calculation (e.g. grid size): ....

- required time averaging and time resolution :
  - ❐ short term/episode
  - ❐ long-term
  - ❐ accidental releases
  - ❐ on-line forecasting (smog warning)
  - ❐ hourly averaged
  - ❐ yearly averaged
  - ❐ statistical values (98 percentile, number of exceedances, maximum values, etc.) please specify:...

- Has the required model accuracy been specified?
  ❐ no
  ❐ yes, namely ....

- Are there any further requirements regarding models or model application? ....
  ....
  ....

- Please specify the models which have actually been applied (names, references, etc.):..

....
....
....
....
....
....
....

8. Do you expect that your requirements regarding models and model applications as described in questions 5 - 7 will change in the near future (1-3 years)?

❒ no, go to question 10

❒ yes, go to question 9

9. Future requirements

(please make copies when the future requirements diverge widely from one application to the other):

- Could you briefly describe the air quality problem (application field, see question 2) for which model results will be used in the future (1-3 years)?

- Briefly describe the extent to which model results will be used in the decision-making process :

❒ exclusively

❒ in combination with AQ-measurements

❒ only in a qualitative way

❒ air quality models will be used in a more integrated approach, that is, they will be coupled with others models, for example with economic process models or with effect

models. Please specify these models ....
....
❐ other: ....
....

Specify as far as possible the required model output:

- type of component to be modelled:
  - ❐ primary components: ❐ SO_2 ❐ NO_x ❐ CO ❐ particles ❐ NH_3 ❐ others:...........
  - ❐ secondary components: ❐ sulphate ❐ nitrate ❐ others: ....
  - ❐ photo oxidants: ❐ O_3 ❐ PAN ❐ others :..
  - ❐ toxic/hazardous (please specify): ....
  - ❐ odour
  - ❐ accidental releases: modelled components:...
  - ❐ other: ....

- modelled quantity: ❐ concentration
  ❐ deposition

- required spatial scale and spatial resolution:
  - ❐ direct surroundings single (point) source
  - ❐ direct surroundings of line sources (traffic)
  - ❐ local scale, multiple sources
  - ❐ special situations, e.g. urban conditions
  - ❐ (sub) national scale
  - ❐ (sub) European scale
  - ❐ spatial density of calculation (e.g. grid size): ....

- required time averaging and time resolution :
  - ❐ short term/episode
  - ❐ long-term
  - ❐ accidental releases
  - ❐ on-line forecasting (smog warning)
  - ❐ hourly averaged
  - ❐ yearly averaged
  - ❐ statistical values (98 percentile, number of exceedances, maximum values, etc.) please specify:...

- required accuracy of the model:
  - ❐ not specified
  - ❐ specified as ....

- Please specify the required documentation of the model: ....
  ....

- Are there any requirements regarding the formats of model input and/or output?.........
  ....
  ....
  ....
  ....
  ....

- Are there any further requirements regarding models or model application? ....

....
....

10. It is planned to prepare a catalogue of operational air quality models. For this model inventory a second questionnaire with detailed questions on model specifications and characteristics will be sent out mid 1995 to persons who are actually involved in model development. Please indicate below persons or institutions who should be contacted.

11. We would be grateful for any further comments on requirements regarding models and model applications.

Thanks for your co-operation!!

note

1. *regulatory: modelling as part of legal or regulatory obligations, for example the calculation of a minimum stack height for new installations*

policy support: modelling studies to support development, formulation, implementation and evaluation of environmental policies; for example, scenario studies on effects of emission abatement measures

assessment: model studies to determine exposure to air pollution and the resulting impact on human health, ecosystems, materials and other environmental compartments.

ANNEX II : MAILING LIST

Questionnaire MA3-1 sent by Topic Centre for Air Quality

National Focal Points

Mr. G. Liebel, Umweltbundesamt, Austria
Mr. A. Derouane, ICE Brussels, Belgium
Mr. T. Iversen, NERI, Denmark
Mr. T. Sãynätkari, National Board of Waters and Env., Finland
Mr. J-L. Weber, IFEN, France
Mr. K. Tietmann, UBA, Germany
Mrs. Aravantinou, Ministry for Env.Physial Planning, Greece
Mr. T. Ibsen, Ministry for Env., Iceland
Mr. L. Stapleton, Env. Prot. Agency, Ireland
Mrs. C. Pera, Ministero dell'Ambiente, Italy
Mr. J-P. Feltgen, Min. de l'Env., Luxembourg
Mr. A. Minderhoud, RIVM, The Netherlands
Mrs. B. Kvæven, Statens Forurensningstilsyn, Norway
Mrs. M.L. Gomes, Min. do Ambiente, Portugal
Mr. A. Herrero, MOPT, Dir. de Political Ambiental, Spain
Mr. E. Kvist, Swed. Env. Prot. Agency, Sweden
Mr. C.D. Martin, Dept. of Env., United Kingdom

Non - EEA member countries

Mr. L. Selfo, Committee for Preservation and Protection, Albania
Mr. O.N. Ivanov, Min. for Foreign Affairs, Belarus
Mr. I. Filipov and Mr. V. Kandev, Min. of Environment, Bulgaria
Mrs. M. Mastrovic, Min. of Civil Engineering, Croatia
Mrs. S. Vidic, Div. Meteorological and Hydrological Service, Croatia
Mr. N. Georgiades, Min. of Agriculture and Nat. Resources, Cyprus
Mr. L. Nicolaides, Env. Pollution, Cyprus
Mr. L. Saare, Min. of the Environment, Estonia
Mr. L. Haszpra, Hungarian Meteorological Service, Hungary
Mr. N. Zoltai, Dept. of Environmental Policy, Hungary
Mr. A. Krikis, Env. Protection, Latvia
Mr. I. Kikis, Head of Foreign Relations, Env. Prot. Dept., Lithuania
Mr. F. Näscher, Landesforstamt, Liechtenstein
Mr. L. Micallef, Min. of Environment, Malta
Mr. D. Drumea, Moldavian Dept. Env. Prot., Moldova

Non - EEA member countries (continued)

Mr. P. Blaszcyk and Mr. G. Mitosek, Inst. of Env. Prot., Poland
Mrs. A. Gheorghe, Min. of Waters, Forestry and Env. Protection, Rumania
Mr. D. Kolganov, State Inst. for Applied Ecology, Russian Fed.
Mr. A. Ryaboshapko, Inst. of Global Climate and Ecology, Russian Fed.
Mrs. M. Mitosinkova, Slovak Hydrometeorological Inst., Slovakia
Mr. D. Svihlová, Min. of Env., Slovakia
Mr. J. Hodalic, Env. Prot. Agency, Slovenia
Mrs. M. Lesnjak, Hydrometeorological Inst., Slovenia
Mr. R. Gehrig, Swiss Federal Laboratories, Switzerland
Mr. P. Ruch, Service Hydrologique, Switzerland
Mr. J. Benes, Cesky Ekologicky Ustav, Czech Republic
Mr. J. Santroch, Czech Hydrometeorological Inst., Czech Republic
Mrs. E.F. Karadag, Min. of the Env., Turkey
Mr. G. Tuncel, Middle East Technical University, Turkey
Mr. V.O. Demkin, Min. for Env. Protection, Ukraine

National Reference Centres

Mr. N. Heidam, Nat. Env. Research Institute, Denmark
Mr. H. Werner, Umweltbundesamt, Germany
Mr. Asimakopoulos, NOA, Greece
Mr. M. Mc Gettigan, Env. Prot. Agency, Ireland
Mr. R. Abbondanza, Min. dell'Ambiente, Italy
Mr. T. Weber, Administration de l'Environnement, Luxembourg
Mr. D. Onderdelinden, RIVM, The Netherlands
Mr. H. Dovland, NILU, Norway
Mr. P. de Pablo Ricote, MOPTMA, Spain

NB1: The list is arranged according to the alphabetical order of the countries, see behind names and affiliation (except for UN/ECE/WHO)