NILU: OR 2/2004

NILU: OR 2/2004
REFERENCE: U-102144
DATE: JANUARY 2004
ISBN: 82-425-1532-8

FUMAPEX

Guidelines of output from UAQIFSs as specified by end-users

Edited by Leiv Håvard Slørdal

Integrated Systems for Forecasting Urban Meteorology, Air Pollution and Population Exposure (FUMAPEX)

FUMAPEX – Deliverable 8.1 Guidelines of output from UAQIFSs as specified by end-users

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Contract number: EVK4-CT-2002-00097
Work package 8: Implementation and demonstration of improved Urban Air Quality Information and Forecasting Systems (UAQIFS)

Contents

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Executive summary

A major goal of the FUMAPEX project is to improve the performance of Urban Air Quality Information and Forecasting Systems (UAQIFS) presently applied in various urban areas in Europe. The scientific focus is on improving the meteorological forecast data that are applied as input to the UAQIFS. The scientific improvements are then to be evaluated through implementation in different UAQIFS with subsequent testing and demonstration in six European target cities. In order to ensure a wide applicability of the project achievements, differences in orographic-, climatic-, and pollution characteristics in various parts of Europe have been used as selection criteria when deciding on target cities. The goal is not just to improve the air quality forecast, but also to ensure that the UAQIFS contain the necessary functionality for a proper dissemination of the forecasts to specific end-users and the public in general. For this reason several end-users are directly involved in the project both as partners and as sub-contractors.

The demonstration activity has been defined as a separate Work Package (WP8) within the FUMAPEX project. The present report (deliverable 8.1) gives a detailed technical specification of each of the UAQIFS, which are to be applied in the demonstration exercise for the following target cities:

- The city of Oslo, Norway.
- The Helsinki Metropolitan area, Finland.
- The Castellon area, Spain.
- The city of Turin, Italy.
- The city of Bologna, Italy.
- The Copenhagen Metropolitan area, Denmark.

It should be noted that while the five first cities in the above list are describing operational day to day urban air quality forecast systems, the UAQIFS for the Copenhagen Metropolitan area is an emergency preparedness system. This system primarily focuses on accidental releases of radioactive materials.

In order to ensure a proper dissemination of the forecasted air quality information the end-users of the project have been heavily involved in the writing of this report. Their main contribution have been in:

- specifying the guidelines for the practical forecasting procedure to be applied in the system,
- defining content and format of needed forecasts and warnings,
- defining the data dissemination to decision-makers, central and local authorities, and to the public in general.

This end-user involvement is also essential in order to promote further application of the scientific achievements within FUMAPEX beyond the three-year project period. The implementation of similar systems in other cities will benefit considerably from the experience gathered through the implementation, testing and demonstration exercise performed in FUMAPEX. Cities like Budapest, Prague, Paris and Vilnius have already shown interest in this type of air quality forecasting systems.

Acknowledgement

This report is part of work package 8 of the FUMAPEX project, which has been funded by the European Commission under the FP5 EESD programme Key Action City of Tomorrow.

FUMAPEX
Guidelines of output from UAQIFSs as specified by end-users

1 Introduction

A major goal of the FUMAPEX project is to improve the performance of Urban Air Quality Information and Forecasting Systems (UAQIFS) presently applied in various urban areas in Europe. The scientific focus is on improving the meteorological forecast data that are applied as input to the UAQIFS. The scientific improvements are then to be evaluated through implementation in different UAQIFS with subsequent testing and demonstration in six European target cities. In order to ensure a wide applicability of the project achievements, differences in orographic-, climatic-, and pollution characteristics in various parts of Europe have been used as selection criteria when deciding on target cities. The goal is not just to improve the air quality forecast, but also to ensure that the UAQIFS contain the necessary functionality for a proper dissemination of the forecasts to specific end-users and the public in general. For this reason several end-users are directly involved in the project both as partners and as sub-contractors.

The demonstration activity has been defined as a separate work package (WP8) within the FUMAPEX project. This work package is entitled "*Implementation and demonstration of improved Urban Air Quality Information and Forecasting Systems (UAQIFS)*". The present report, which constitutes Deliverable 8.1 as stated in the FUMAPEX DoW, gives a detailed technical specification of each of the UAQIFS, which ultimately are to be applied in the demonstration exercise for the selected target cities. In order to ensure a proper dissemination of the forecasted air quality information the end-users have been heavily involved in the writing of this report, especially in the part concerning the design of the forecast procedure.

This report describes the UAQIFS to be applied in:

- The city of Oslo, Norway.
- The Helsinki Metropolitan area, Finland.
- The Castellon area, Spain.
- The city of Turin, Italy.
- The city of Bologna, Italy.
- The Copenhagen Metropolitan area, Denmark.

It should be noted that while the 5 first cities in the above list are describing operational day to day urban air quality forecast systems, the UAQIFS for the Copenhagen Metropolitan area is an emergency preparedness system. This system primarily focuses on accidental releases of radioactive materials.

In the following sections the UAQIFS to be applied in each of the six target cities are described separately. To facilitate readability all of the sections have been structured as consistently as possible. However, because of differences both in methods and in the present state of system operationality, some nonconforming features will be found in the text layout.

2 Guidelines on the output from the UAQIFS for the city of Oslo, Norway

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2.1 Description of the presently applied Operational UAQIFS for OSLO

The basis for the presently applied UAQIFS in Oslo is a combined model consisting of the Meteorological Institute's meteorological model MM5 and NILU's dispersion model AirQUIS. The final AQ forecast is distributed to the public by Oslo Public Health Authority (end-user). These forecasts are issued every day during the winter season from about 1 November until 1 May.

In section 2 below a general description of the presently applied UAQIFS is given. In section 3 the end-users, in collaboration with the modellers, have constructed a guideline for the forecast procedure, thereby defining the desired output from the forecasting system.

2.1.1 Meteorological models and Computer system at met.no

The main objective of the operational NWP system at met.no is to provide meteorological forecasts for Northern-Europe and the adjacent ocean area, and is therefore closely connected to Norwegian interests. This system includes the HIRLAM model (Unden, 2002), which daily produces forecasts with 10 km (HIRLAM10) and 20 km (HIRLAM20) resolution. In the ongoing project, Improved City Air, the operational system for prediction of peak pollutions consists of a meteorological model (MM5/HIRLAM10) and the air pollution dispersion model AirQUIS, developed by NILU (Berge et al., 2002).

Initial and boundary conditions to the MM5 simulations are collected from the 24-48h forecast of HIRLAM10 to provide the authorities time to implement the practical details and inform the public of eventual restrictions.

2.1.2 MM5

To better simulate small-scale circulations generated by local topography and open water bodies within the city, version 3.4 of the non-hydrostatic Fifth-Generation Penn State/NCAR Mesoscale Model (MM5) is used. MM5 is described in detail by Dudhia (1993, 1996) and Grell et al. (1994), and documentation on different versions is available from http://www.mmm.ucar.edu/mm5/.

The operational MM5 configuration consists of an outer 3 km horizontal resolution grid and an inner mesh with 1km horizontal resolution, covering a quite large area around Oslo. The horizontal grid has 77 * 66 grid points. Both integration areas have 17 vertical layers (9 below 1500m). The MM5 model has several different choices for physic options. The physic options in use are a first order turbulence closure (Hong and Pan, 1996), a 5-layer soil model with prescribed land-use dependent soil moisture availability, explicit moist physics including ice phase, and no parameterisation of cumulus and shallow convection. Topography and land-use are collected from the U.S. Geological Survey (USGC). At 60° north this data has a 0.5km * 0.9km horizontal resolution. In Figure 2.1 the topography for the inner mesh is shown and Table 2.1 describes different land-use categories in use with their physical properties.

Table 2.1: Land-use categories in MM5, with prescribed values of different physical properties.

Land-use category	Albedo (%)	Surface emissivity (fraction)	Soil moisture (fraction)	Roughness length (cm)	Description
1	18	0.88	0.10	100	Urban and built-up land
2	23	0.92	0.60	5	Dry land cropland and pasture
5	23	0.92	0.40	5	Cropland/grassland mosaic
6	20	0.93	0.60	20	Cropland/woodland mosaic
8	25	0.88	0.20	10	Shrub land
11	17	0.93	0.60	50	Deciduous broadleaf forest
12	15	0.93	0.60	50	Deciduous needle leaf forest
14	12	0.95	0.60	100	Evergreen needle leaf forest
15	14	0.94	0.60	50	Mixed forest
16	8	0.98	1.00	0.01	Water bodies
18	14	0.95	0.70	40	Wooded Wetland
24	70	0.95	0.95	5	Snow or ice

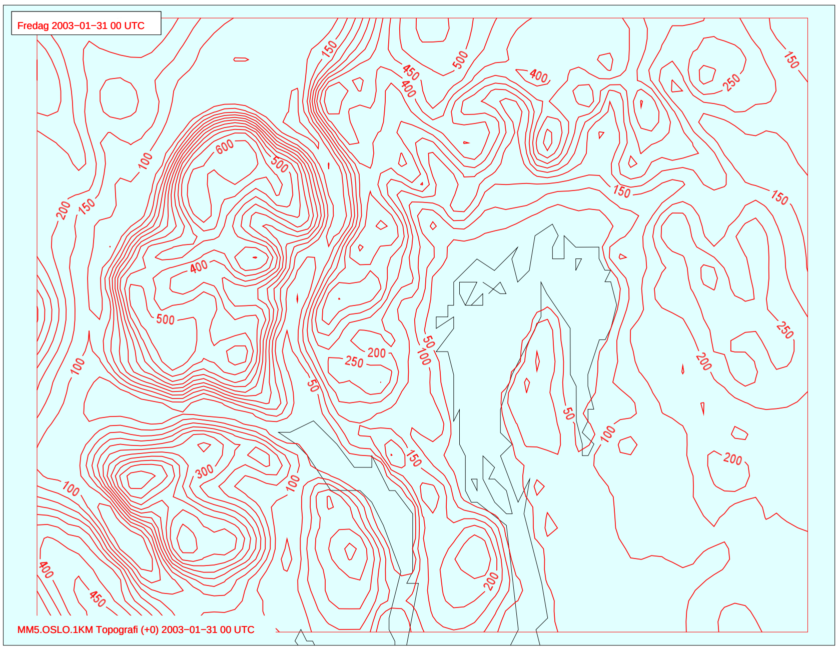


Figure 2.1: Topography for the MM5 domain covering the Oslo region (contour interval in meter).

2.1.3 The meteorological pre-processor

A meteorological pre-processing interface is translating/interpolating the model output of MM5 so as to meet the input requirements of the AirQUIS modelling system. The pre-processor takes care of the following tasks:

- *Space interpolation:* The two models are defined with as equal spatial and temporal resolution as possible to avoid use of extensive spatial interpolation.
- *Change of coordinate grid system:*
  - Horizontally: From the polar stereographic projection in MM5, to the EPISODE grid defined in UTM–coordinates.
  - Vertically: From a normalized pressure (sigma) in the vertical (see MM5 description) to a terrain following σ-transform (transforming from the Cartesian height z) in EPISODE. The model layers are defined approximately at the same physical heights.
- *Meteorological input variables transferred from MM5:*
  - 3-D: Horizontal wind components, temperature.
  - 2-D: Precipitation, relative humidity, vertical temperature difference between the two lowest model layers, land-use classification, and surface roughness.

The vertical velocity applied in AirQUIS is recalculated based on the gridded horizontal wind field from MM5 and the additional physical requirement of having a mass consistent (divergence-free) wind field.

In the present forecast version the meteorological input required by AirQUIS is just extracted from MM5 as if these were observed values. The dispersion parameters for the air quality forecast are then calculated using traditional Monin-Obukhov similarity theory following the methods of van Ulden and Holtslag (1985), (Bøhler, 1996). <u>An important part of the FUMAPEX project</u> is to review this coupling between MM5 and AirQUIS in order to describe the dispersion conditions more consistently, thereby optimising the use of the meteorological information from the MM5 prognosis.

The metrological pre-processor is run either on a PC or a UNIX Workstation, and the programming language is FORTRAN.

2.1.4 The air quality modelling system, AirQUIS

The air quality forecast is made by the PC-based Air Quality Information System, AirQUIS (Bøhler and Sivertsen, 1998; http://www.nilu.no/aqm/). This system has been developed at NILU over the last years and has been applied for estimating urban Air Quality in several cities (Laupsa and Slørdal, 2002; Wind et al., 2003). The combination of functionalities for emission inventory and numerical modelling within an operable and functional GIS platform makes AirQUIS an effective UAQIFS tool.

The dispersion model within AirQUIS (EPISODE) is an Eulerian grid model with use of embedded subgrid line and point source Gaussian models for near source treatment (Slørdal et al., 2003; Grønskei et al., 1993). The model estimates urban background concentration levels, and near source concentrations from road transport and individual stacks.

In the Improved City Air project AirQUIS is applied on a 1 km resolution grid for the city of Oslo. The model domain (with topography and main road network depicted) is shown in Figure 2.2. Air Quality forecasts are made for NO_2, PM_{10}, and $PM_{2.5}$.

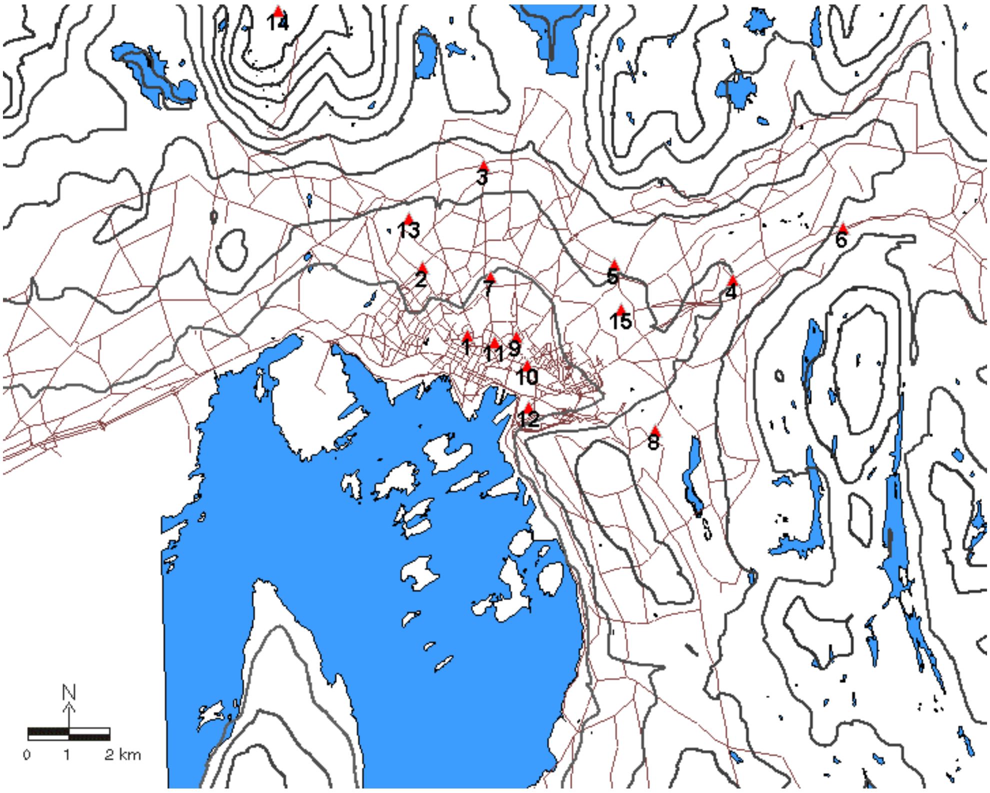


Figure 2.2: AirQUIS model domain for the city of Oslo. The topography is given with thick dark contour lines (50 m equidistance) and the main road network is indicated with thin lines. The available AQ and met. measurement stations are depicted with numbered red triangles. (AQ-stations numbered 1 to 12, and met. stations 13 to 15).

The AirQUIS emission inventory module contains data such as fuel consumption, emission factors, physical description of stacks and processes, traffic load etc. Estimates of hourly emissions of the different air quality components are then calculated by application of the emission model. The emission data are split into three separate categories. These are:

- **Point source emissions:** Include emissions from industrial plants or large factories.
- **Line source emissions:** Include all emissions from road traffic. In the calculations only roads with annual daily traffic (ADT) above a user defined limit value are included as line sources. The emissions from the roads with lower ADT are treated as area sources.
- **Area source emissions:** Include both stationary sources that are too small to be regarded as point sources as well as road traffic emissions from roads with ADT below a given user defined limit.

The method applied to calculate the PM_{10} contribution from traffic-induced resuspension takes into account the effect of vehicle composition, traffic speed and, during the winter season, the percentage of vehicles with studded tyres, on each road segment. Since practically no particles are resuspended when the roads are wet, hourly data on relative humidity and precipitation within the modelling area have been included as input to the emission model.

As mentioned in the section describing the meteorological pre-processor, the necessary dispersion parameters are calculated within AirQUIS using traditional Monin-Obukhov similarity theory (van Ulden and Holtslag, 1985; Bøhler, 1996). Utilizing this theory in combination with the meteorological data extracted from MM5, important quantities like the mixing height, and the vertical profile functions of the surface layer wind, temperature, turbulence parameters (σ_v and σ_w) and the vertical exchange coefficient (K_z) are estimated.

AirQUIS also contains a population exposure module. This module combines the calculated outdoor concentration levels with information on the geographical distribution of the city inhabitants. The applied population distribution is stationary and is based on information on home addresses. In the air quality forecast the exposure estimates are employed as an aid when assessing the health impacts of a forecasted pollution episode.

AirQUIS is run on a PC (WINDOWS, 98, 2000, NT, and XP), and the programming language is Visual Basic (VB). The dispersion model (EPISODE) is programmed in FORTRAN 90 and compiled as a Dynamic Link Library (DLL) for application within the AirQUIS' VB environment.

2.1.5 Forecast procedure

The forecast model is operated in the following way (Figure 2.3):

(1) The HIRLAM10 is run every morning (for a 00- 48 hours prognosis) on the national super computer based on input from global and regional models. This run is finished at about 05 local time (LT).

(2) Initial and boundary values from HIRLAM10 are utilized to run the fine-scale meteorological model MM5 (1 km resolution) for the Oslo region for the period +24 to +48 hours since the local forecasts first of all is needed for the next day. Runs are performed on a local Linux-cluster (20 processors), and it is finished at about 06 LT.

(3) A meteorological pre-processor extracts the MM5 information needed by AirQUIS. AirQUIS is then run for Oslo (+24 to +48 hours) on a dedicated PC. The AQ-forecast is finished around 06:30 LT.

(4) The (quantitative) AQ and MM5 forecast (e.g. model output plots) and duty forecasters interpretation and comments to MM5 results for the next day are distributed to the end-user by a WEB-page. All information for Oslo is available at about 07 LT.

(5) The end-user, (Public Health Authority, the Municipality of Oslo) receive the quantitative forecast and issues a public forecast for the next day at about 07:30 LT. An example of the form of this forecast is shown below in Figure 2.4.

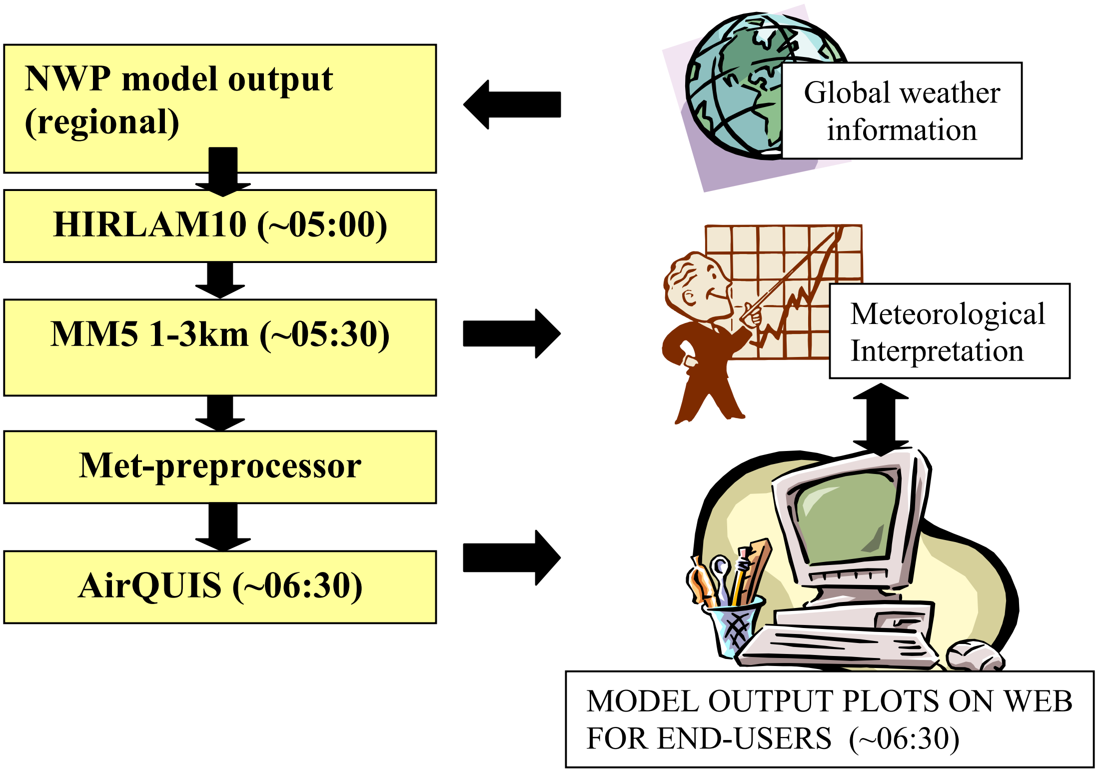


Figure 2.3: The existing operational forecast model for Oslo.

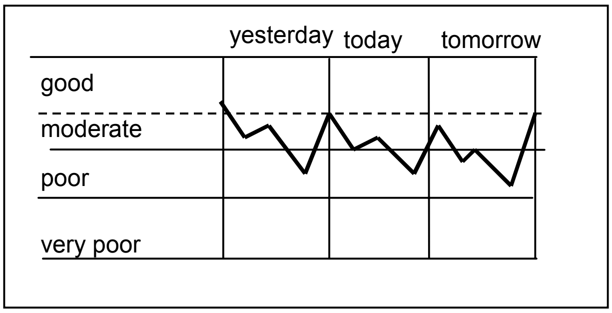
Forecast of air quality

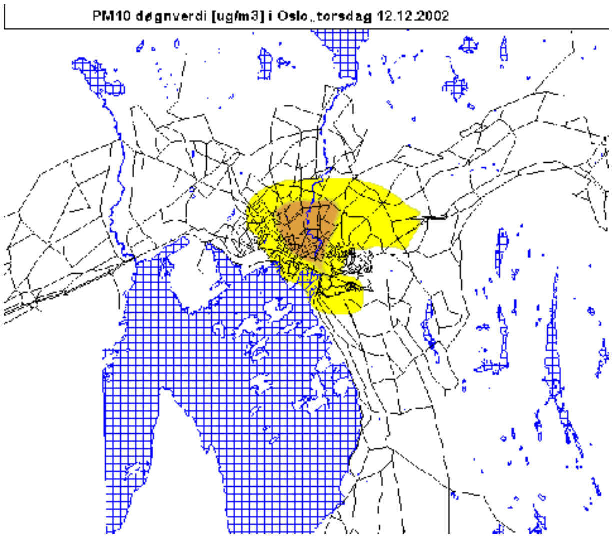
from the Oslo Public Health Authority

Forecast for Oslo:

- The air quality was **moderate** Wednesday 11 December at 8 a.m. The air quality is expected to be **moderate** this morning and **poor** in the afternoon and evening within Ring 2. The cause of the pollution is mainly wood burning. The air quality is expected to be **good** in other areas.

- Forecast for Thursday 12 December. The air quality is expected to be **poor** in lower parts of Groruddalen and within Ring 2. The cause of the pollution is exhaust and wood burning. The air quality is expected to be **good** in other areas.





HEALTH EFFECTS IN RELATION TO THE AIR QUALITY CLASSES

Level	***Health Effects***
Good	No health effects
Moderate (Yellow)	Asthmatics may experience health effects in streets with heavy traffic, especially during physical activities.
Poor (Orange)	Asthmatics and people with serious heart- and bronchial diseases should avoid longer outdoor stays in areas with high air pollution.

Figure 2.4: Example of an air quality forecast from the Oslo Public Health Authority. (The present forecast is made in Norwegian.)

2.2 End-user guideline for forecasting procedure

Below the Oslo Public Health Authority and the Norwegian Traffic Authorities (end-users in the FUMAPEX project) have defined a detailed guideline for the forecasting procedure in close collaboration with the modelling groups at met.no and NILU. This guideline gives a detailed description of the output from the UAQIFS as requested by the end-users. The proposed procedure is very similar to the presently applied forecasting procedure, with some changes/additions to be incorporated in the new UAQIFS. The procedure description below can therefore be considered as the end-users input to the technical specification of the UAQIFS to be developed within the FUMAPEX project for the city of Oslo.

- The results from the combined meteorological and air quality model has to be ready at 7 a.m. local time at the latest. The results should be available on the Internet for the end-users.
- The results from the MM5 model should include surface data of wind, temperature and precipitation and prognostic vertical profiles (wind, temperature, relative humidity) for every three hours from + 6 to + 48 hours ahead. Precipitation data should be for every 0,1 mm. The presentation of the output results should be as user-friendly as possible, i.e. easy to interpret also by non-meteorologists.
- The AirQUIS model should calculate the concentrations of NO_2, PM_{10} and $PM_{2,5}$ for every hour at the monitoring stations in the city. The data should be available in an easy-to-read table on the Internet site. The model should also give maps of the air quality situation in the city (24 maps of hourly concentration for NO_2 and 1 map each for daily concentrations of PM_{10} and $PM_{2,5}$).
- The AirQUIS model should calculate the total human exposure within the different forecasting classes. This is related to a national guideline that says that more than 20.000 persons need to be exposed above a given forecasting class for this class to be forecasted for the city. The four forecasting classes used are defined in Table 2 below.
- Based on the model results, monitoring data and experience, the person responsible for the forecast at the Oslo Public Health Authority (end-user) should formulate a subjective air quality forecast for today and tomorrow. A graph showing the variation in the pollution level yesterday, today and tomorrow should be produced on the basis of the component (NO_2, PM_{10} or $PM_{2,5}$) with highest concentration at any time. The maximum values of PM_{10} and $PM_{2,5}$ are here defined as the maximum running 24-hour average. The chosen forecasting class will mostly be based on the human exposure calculations. The air quality forecasts should also include a text explaining when and where the pollution is expected to be highest in the city, which areas the air quality is supposed to be good, the health effects in the different forecasting classes, and which sources that are believed to be the main contributors to the pollution. If the air pollution is high, the forecasts should also urge the public to take actions to contribute to a lower pollution level. If the calculated air quality maps are believed to be good/correct, one or more maps should be published with the forecast.

- The forecast should be ready to be published at 8.30 a.m. at the latest (Monday – Friday). This deadline refers to the local afternoon newspaper that prints the forecast and to the local radio station. During weekends the deadline is 10.45 a.m. The forecast will also be sent to a mailing list of people who want the forecasts directly (this service is free and for everyone) and published on the Internet.

Table 2.2:National forecasting classes for local air quality.

Level	NO_2 (hour)	PM_{10} (running 24-hour)	$PM_{2,5}$ (running 24-hour)	Health effects
Good	< 100	< 35	< 20	No health effects
Moderate	100 - 150	35 - 50	20 - 35	Asthmatics may experience health effects in streets with heavy traffic, especially during physical activities.
Poor	150 - 200	50 - 100	35 - 60	Asthmatics and people with serious heart- and bronchial diseases should avoid longer outdoor stays in areas with high air pollution.
Very poor	> 200	> 100	> 60	Asthmatics and people with serious heart- and bronchial diseases should avoid areas with very high air pollution. Healthy people may experience incidentally irritations in the muscular membrane and unpleasantness.

[1] A forecasting class is based on expected maximum levels for one of the three components during the topical period.

2.3 References

About AirQUIS: http://www.nilu.no/aqm/

Berge, E. and Køltzow, M.Ø. (2002). Winter climate of Bjørvika, Oslo, described by MM5. Oslo, The Norwegian Meteorological Institute (Research Report no. 142) (in Norwegian).

Berge, E., Walker, S-E., Sorteberg, A., Lenkopane, M., Eastwood, S., Jablonska, H.I. and Køltzow, M.Ø. (2002) A real-time operational forecast model for meteorology and air quality during peak air pollution episodes in Oslo, Norway. *Water, Air and Soil Pollution Focus, 2*, pp. 745-757.

Bøhler, T. (1996) MEPDIM. The NILU Meteorological Processor for Dispersion Modelling. Version 1.0. Model description. Kjeller (NILU TR 7/96).

Bøhler, T. and Sivertsen, B. (1998) A modern Air Quality Management system used in Norway. Kjeller (NILU F 4/98).

Dudhia, J. (1993) A nonhydrostatic version of the Penn State/NCAR mesoscale model: validation tests and simulation of an Atlantic cyclone and cold front. *Mon. Wea. Rev., 121,* 1493-1513.

Dudhia J. (1996) A multi-layer soil temperature model for MM5. In: *Preprints, The sixth PSU/NCAR Mesoscale Model Users Workshop, 22-24 July 1996, Boulder, Colorado.* pp. 49-50.

Grell, G., Dudhia, J., and Stauffer, D. (1994) A description of the Fifth-Generation PENN STATE/NCAR Mesoscale Model (MM5). Boulder, Colorado, National Center for Atmospheric Research (NCAR Technical Note, NCAR/TN-398+STR).

Grønskei, K.E., Walker, S.E. and Gram, F. (1993) Evaluation of a model for hourly spatial concentrations distributions. *Atmos. Environ.*, *27B*, 105-120.

Hong, S.-Y. and Pan H.-L. (1996) Nonlocal boundary layer vertical diffusion in a medium range forecast model. *Mon. Wea. Rev., 124*, 2322-2339.

Laupsa, H. and Slørdal, L.H. (2002) Applying model calculations to estimate urban air quality with respect to the requirements of the EU directives on NO_2, PM_{10} and C_6H_6. In: *Proceedings of the Eight International Conference on Harmonisation within atmospheric dispersion modelling for regulatory purposes*. Sofia, Demetra Ltd. pp. 429-433.

Slørdal, L.H., Solberg, S., and Walker, S.E. (2003) The urban air dispersion model EPISODE applied in $AirQUIS_{2003}$. Technical description. Kjeller (NILU TR 12/2003).

Unden, P. (ed.) (2002) HIRLAM-5 Scientific Documentation. Norrköping, SMHI.

van Ulden, A.P. and Holtslag, A.A.M. (1985) Estimation of atmospheric boundary layer parameters for diffusion application. *J. Appl. Meteorol., 24*, 1196-1207.

Wind, P., Tarrason, L., Slørdal, L.H., Solberg, S., Denby, B., and Walker, S.E. (2003) Development of a modelling system able to link hemispheric-regional and local air pollution. Oslo, The Norwegian Meteorological Institute (Joint MSC-W & NILU Note 2/03). http://www.emep.int/reports/emep_note_2_2003.pdf

3 Guidelines on the output from the UAQIFS for the Helsinki Metropolitan Area, Finland

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3.1 Description of the presently applied Operational UAQIFS for Helsinki

The methods for air quality forecasting (AQF) are essential for predicting the worst air quality situations. Air quality forecasts and warnings in case of possibly occurring peak pollution episodes produced by the Finnish Meteorological Institute (FMI) are forwarded to the Helsinki Metropolitan Area Council (YTV) on a continuous basis. The final AQ forecast is distributed to the public by YTV as the end-user.

The present system is the API-FMI, Air Pollution Information System for disseminating real-time and forecasted air pollution information to the public. The system includes computational methods for forecasting air pollution in time (Bremer, 1993, Bremer and Valtanen, 1995), a mathematical model for computing an air quality index and a system for disseminating the results to the public in an easily readable form. Air pollution forecasting is divided into two steps:

(i) application of the weather forecasts of the synoptic situation and meteorological parameters
(ii) computation of pollutant concentrations, using statistical methods and the urban dispersion modelling systems, UDM-FMI or CAR-FMI.

The statistical methods are based on regression analysis of measured concentrations and meteorological parameters. These correlations have been derived from measurements in the Helsinki metropolitan area. Air pollution forecasts are made for the compounds SO_2, NO_x and CO. The system is applicable in an urban area. It is also prognostically, as a warning system for high pollution concentrations.

The urban dispersion modelling system (UDM-FMI; Karppinen et al., 1998) includes a multiple source Gaussian plume model and the meteorological pre-processor. The dispersion model is an integrated urban-scale model, taking into account all source categories (point, line, area and volume sources). It includes a treatment of chemical transformation (for NO2) and deposition (dry and wet deposition for SO_2), plume rise, downwash phenomena and the dispersion of inert particles.

In addition a Meteorological Air Quality Index (MAQ), an application for forecasting of air pollution episodes during Northern European winter-time weather conditions, has been implemented during 2002. The application is based on evaluating the air pollution potential from the HIRLAM forecast and the result is then presented as a single index value (MAQ index, meteorological air quality index). The most important parameters in determining the index value are the occurrence and strength of surface inversion and wind speed near the surface. The air quality forecast was made for the next day (i.e. for +24..48h from the time of the HIRLAM forecast). The MAQ is used by duty forecasters at the FMI for evaluating the air quality situation inside Helsinki Metropolitan Area. Some verification of the MAQ index has been conducted against the observed NO_2 concentrations in Lahti, Turku and the Helsinki Metropolitan Area. The preliminary results show, that although problems in the HIRLAM model boundary layer modelling decrease the accuracy of the predictions, the MAQ index follows the general NO_2 concentration accumulation relatively well. The MAQ index can not predict particulate matter episodes.

3.1.1 Meteorological model

Since April 2003, the operational NWP model at FMI has been HIRLAM (High Resolution Limited Area Model) version 5.1.4, which is also the current HIRLAM reference version maintained by the international HIRLAM project. Currently, the model produces daily four 54 hour regional and mesoscale forecasts.

HIRLAM is hydrostatic, prognostic numerical weather model, which has hybrid coordinate system in the vertical and staggered Arakawa-C-grid in the horizontal (Eerola, 2000). In implementation the south pole is a rotated at longitude/latitude 0/-30°. Within the international HIRLAM project, a non-hydrostatic version has been developed, the code being written in Tartu University, Estonia (Rõõm, 2001). This non-hydrostatic version is also available for FMI, but is not operational.

The horizontal resolution of version 5.1.4 (ATX) is 0.3° or 33 km at 60°N, compared to earlier (version 4.6.2) resolutions of 0,4° (ATA) and 0,2° (ENO). Version 5.1.4 covers approximately same domain as the earlier ATA-version (see Figure 3.1). The vertical resolution of ATX is 40 layers, as compared to earlier 31 layers (ATA and ENO).

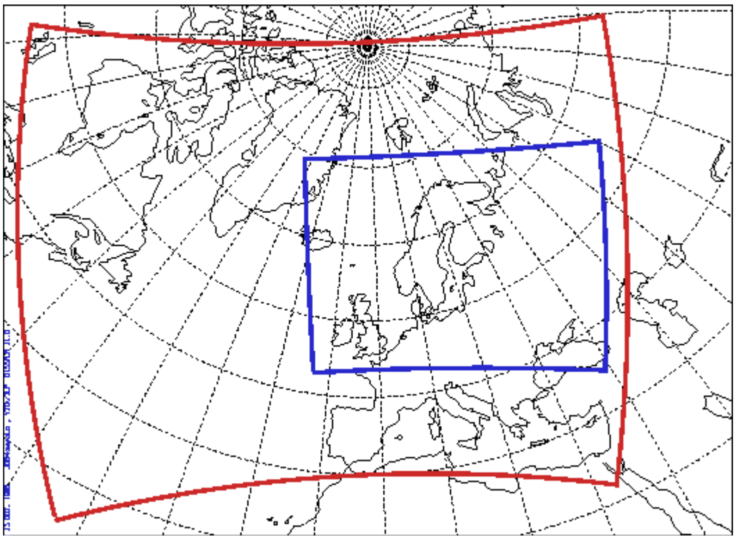

Figure 3.1: Approximate model domains used for the HIRLAM versions ENO 4.6.2 (smaller) and ATA 4.6.2 (larger) (Eerola 2000). The domain of the latest reference version 5.1.4 (ATX) is approximately the same as the larger domain shown in the figure.

In the operational implementation a Davies-Kållberg relaxation scheme applied for the staggered grid is used. The lateral boundary fields for the largest integration area are obtained from ECMWF. Inside HIRLAM 1-way nesting procedure is used.

In assimilation of meteorological observations three-dimensional variational data assimilation with digital filter initialization is used.

Topography (orographic height) is derived from the GTOPO30" data base. Other physiography fields are based on several data bases with variable resolutions. For surface parameterisation scheme ISBA scheme with five surface subtypes in each grid square (Navascués et al., 2002) is used. The turbulence in the atmospheric boundary layer (ABL) is based on TKE and diagnostic length scale approach (Cuxart et al, 2000). Condensation parameterisation and cloud microphysics are based on the cloud condensate as a prognostic variable (a modified Sundqvist scheme), convection is based on Kuo-type closure (Sundqvist et al., 1989, Kuo 1974). A fast radiation scheme (Savijärvi, 1990), with LW and SW radiation handled separately, is being used.

The operational platform for HIRLAM is IBM Power 4 supercomputer. The development, testing and research runs are done Linux PCs and SGI AIX servers. The operational model is integrated to +54 hours forward in time, starting at 00, 06, 12 and 18 UTC, daily. The HIRLAM meteorological output is in GRIB data format.

3.2 Description of the future developments in the Operational UAQIFS

3.2.1 The air quality forecast system

Possibilities of developing of a new system for UAQIFS in Helsinki Metropolitan Area (Helsinki, Vantaa, Espoo, Kauniainen) based on FMI’s local scale dispersion model CAR-FMI are being studied. In the new system the air quality forecast would be made with two PC-based dispersion models linked to HIRLAM through FMI’s RealTime Database. The current operational models are the vehicular dispersion model for evaluating the dispersion of pollution from a road network (CAR-FMI) and a street canyon dispersion model (OSPM).

The interface between CAR-FMI and HIRLAM is a query-data interface. The meteorological post processing is done by the metPostProc program, which deals with the reading of the meteorological data and the conversion of cumulative values to instant values (e.g. heat and momentum fluxes). The calculation of atmospheric boundary layer parameters (e.g. Monin-Obukhov mixing depth) and construction of meteorological time-series for CAR-FM is done with MPP-FMI, which is meteorological pre-processor for FMI’s Urban Dispersion Modelling System (FMI-UDM).

The relevant meteorological parameters for the local-scale models are evaluated by a meteorological pre-processing model (Karppinen et al., 1998, 2000). The model is based mainly on the energy budget method of van Ulden and Holtslag (1985). The model utilises the synoptic meteorological observations and the meteorological sounding observations. The model estimates the hourly time series of the relevant atmospheric turbulence parameters (the Monin-Obukhov length scale, the friction velocity and the convective velocity scale) and the boundary layer height. Within COST 710 project, the predictions of the FMI pre-processor were found to be overall in fair agreement with those of the pre-processor developed in Denmark and Sweden. Recently, the model has been refined in order to better allow for urban conditions.

The urban dispersion modelling system (UDM-FMI) is a multiple source Gaussian plume model and the meteorological pre-processor system. The dispersion model is an integrated urban scale model, taking into account all source categories (point, line, area and volume sources). It includes a treatment of chemical transformation (for NO_2) and deposition (wet deposition, and dry deposition for SO_2 and NO_2), plume rise, downwash phenomena and dispersion of inert particles. The model allows also for the influence of a finite mixing height. The dispersion module of the system utilises input emission data, pre-processed meteorological data and geographical data. The dispersion module computes hourly time series of the concentrations of pollutants. The system also computes statistical parameters from the time series, which can be compared to air quality guidelines (for instance, various percentile values). The system can be used on a Cray supercomputer or on a workstation.

3.2.2 The models to be implemented

CAR-FMI (Contaminants in the Air from the Road - Finnish Meteorological Institute) (Härkönen et al., 1996) is an open area/line source model CAR-FMI is developed for modelling the dispersion of traffic origin nitrogen monoxide (NO), nitrogen dioxide (NO_2), total of nitrogen oxides (NO_x), carbon monoxide (CO), and exhaust fine particles ($PM_{2.5}$) in the user defined size of the study area. The influence of different kinds of roads, traffic volumes and driving speeds can be studied. The model is relatively easy to use due to the clear and logical PC-based user interface. CAR-FMI computes automatically statically analysed concentrations, which are directly comparable with the air quality standards, important in the regulatory work. The results can be presented in a map surface using a Geographical Information System (GIS), e.g. MapInfo.

CAR-FMI is developed for the roads in open environment, and thus, it cannot take the individual obstacles into account. In case of $PM_{2.5}$, only primary emissions are included to the model at the moment. Thus, the modelling accuracy is not yet the best possible in case of $PM_{2.5}$ concentrations. The surrounding terrain of the roads is taken into account by average roughness of the area. The influence of individual obstacles or vegetation on dispersion of air pollutants can be only roughly taken into account. Therefore, the proper height to locate apartments, nor the air quality at the inner court of the buildings, cannot be taken into account. A suitable model for these types of cases should be used in to include these, e.g. the street canyon model OSPM. CAR-FMI does not include of the influence of certain restrictions, such as, traffic lights and roundabouts to air quality. The effects of accelerations and decelerations on the emitted emissions can be taken into account in some extent in emission factors as averaging values.

The Operations Street Pollution Model (OSPM) is a practical street pollution model based on simplified description of flow and dispersion conditions in street canyons (Hertel and Berkowicz, 1989). Concentrations of exhaust gases are computed using a combination of a plume model for the direct contribution from street traffic, and a box model for the recirculating part of pollutants in the street. The simplified parameterisation of the flow and dispersion conditions in a street canyon has been deduced from extensive analysis of experimental data and model tests. The emission field is treated as an area source at street level. The wind direction at street level is assumed to be mirror-reflected with respect to that of the roof level wind, and attenuated according to a simple logarithmic profile. The transport wind is calculated at the average height of vehicles, h0 = 2 m. Due to the presence of the flanking buildings, crosswind diffusion is neglected.

The hourly mean concentrations are calculated assuming wind meandering with an angle increasing with decreasing wind speed. The vertical dispersion parameter is modelled assuming that dispersion of the plume is governed solely by mechanical turbulence. Turbulence due to thermal stratification has been neglected, as its influence is usually negligible at street level. The mechanical turbulence is assumed to be generated by the wind and by the traffic in the street. Traffic-induced turbulence plays an important role in the dispersion of pollutants in a street, particularly in low wind-speed conditions (Berkowicz et al., 1997).

The contribution from the recirculation part is computed using a simple box model. It is assumed that the canyon vortex has the shape of a trapezium, with the maximum length of the upper edge being half the vortex length. The ventilation of the recirculation zone takes place through the edges of the trapeze, but the ventilation can be limited by the presence of a downwind building. The model can also be applied to dispersion in streets with spread-out buildings or buildings on one side only.

Considering the chemical transformation in a street canyon, only the fastest chemical reactions can have any significance. For nitrogen oxides, it is therefore sufficient to include only the basic reactions involving NO, NO_2, O_2 and O_3. The model includes the three basic reactions between these compounds.

For the calculation of NO_2 formation in the street, the urban background concentrations of nitrogen oxides and ozone must be given as input. Temperature and total solar radiation are also needed as input values for the model in order to compute the chemical reaction coefficients. The urban background concentrations must also be given for the other pollutants (e.g., CO, benzene) calculated by the OSPM model. Often these are available from measurements, but an urban background model can also be used to provide these input parameters.

3.2.3 The Structure of CAR-FMI

CAR-FMI (Contaminants in the Air from a Road) (Härkönen et al., 1996; Härkönen, 2002) computes the concentrations of carbon monoxide (CO), nitrogen monoxide (NO), nitrogen dioxide (NO_2), nitrogen oxides (NO_x), ozone (O_3), and exhaust fine particle matter ($PM_{2.5}$). The model is based on a partly analytical solution of the Gaussian diffusion equation for a finite line source and the dry deposition for $PM_{2.5}$ (Härkönen, 2002a).

Two versions CAR-FMI have been developed. One version is designed for desktop computers and the other for UNIX-mainframe (e.g. Cray C94). Desktop version of CAR-FMI model utilises Windows based user interface, and is designed to be used by end users, e.g. by city authorities. The mainframe version of CAR-FMI is mainly used for AQ assessments and for research. The main difference between the versions is in the computation capabilities. The mainframe version of is recommended, if the amount of input data, or the region of interest, is very large.

The desktop version of CAR-FMI the maximum length of time series is limited to one year, whereas in the mainframe version computation time series can cover three or five years. The output of desktop version contains statistically analysed concentrations in each receptor point. The output of mainframe version consists of continuous hourly time series of concentrations.

The model CAR-FMI includes a chemical transformation model, a dispersion model, and an emission model. The chemical transformation model contains basic reactions for nitrogen oxides, oxygen and ozone. The transformation uses discrete parcel method, which considers that the emissions and the background air are uniformly mixed in the air parcels. The size of the reaction volume is dependent on the receptor location (Härkönen et al, 1997).

The model uses general solution of the Gaussian diffusion equation for a finite line source for the dispersion of the gaseous pollutants (Härkönen, 2002). The dispersion of exhaust particle matter is determined according to the work of Kerminen et al. (1997) and dry deposition velocity is determined according the work of Nikmo et al. (1997). The structure of emission model is independent on emitted compounds. The emission model includes motor emissions for CO, NO_x, and $PM_{2.5}$. Exhaust emission as a function of the average driving speed is fitted separately for six different vehicle categories. The height of which the emissions are released is 1.0 m above the road.

The schematic diagram of the modelling process of CAR-FMI is shown in Figure 3.2. The input information includes the size and location of the region of interest, detailed information of the roads investigated, location of the roads and the average traffic speed, volume, and composition on the roads in question. In addition, the model needs as an input the information about the average temporal variation of traffic volumes, meteorological and background concentrations, and emissions.

The basic emission in CAR-FMI is a straight line source. The road has to be divided into smaller parts if it has a significant change in direction or if there are significant changes in vehicle volume, driving speed, or in proportion of different vehicle categories. Traffic information must include traffic volume (in vehicles/day), driving speed (in km/h), vehicle distribution (in %) and traffic weights, determined separately for each road. Vehicle distribution includes the proportion of heavy duty vehicles (HDV) of total vehicles, proportion of lorries of HDV's, lorries with trailers of lorries, diesel busses of busses, petrol cars of light duty vehicles (LDV), and petrol vehicles with catalytic converter. Traffic weights information is determined by individual data file. It contains coefficients for monthly and hourly traffic volumes. Traffic weights data indicates the time behaviour of traffic.

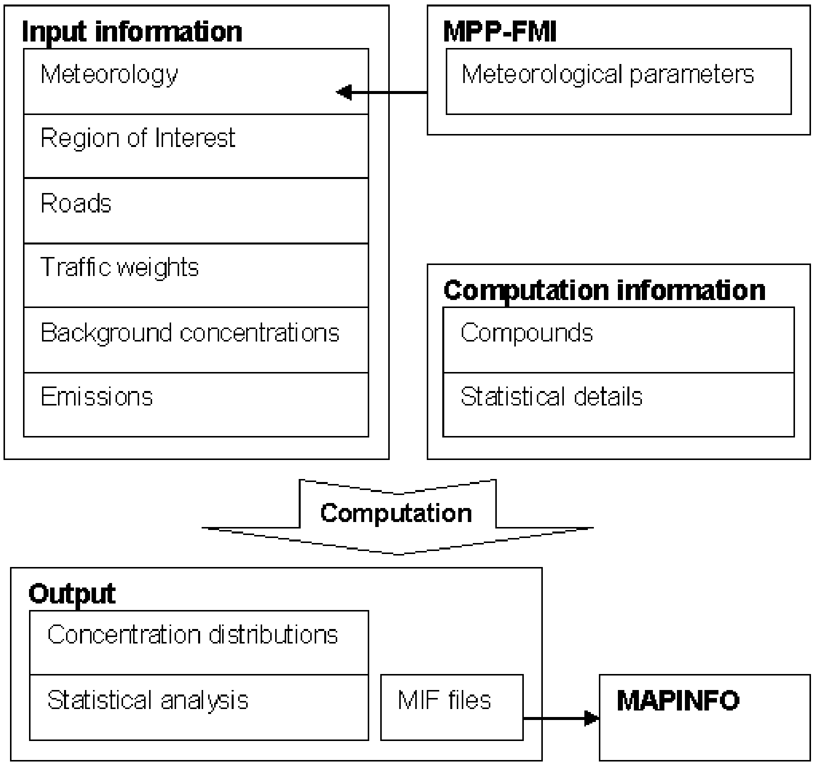

Figure 3.2: The general flow of CAR-FMI. MPP-FMI is meteorological pre-processing model (Karppinen et al., 1997); MIF is file format that enables the results of CAR-FMI model to be presented with MapInfo software (GIS, Geographical Information System).

Level of emissions as a function of driving speed for different vehicle types is determined by emission factors. The emission factors for exhaust emissions are polynomial and exponential fittings over the driving speed range 1-120 km/h. In addition to driving speed, emissions factors depend on vehicle and fuel type. Vehicles are classified in six separated classes (see Figure 3.3). Categories for light-duty vehicles (LDV) are gasoline-powered cars and vans equipped with catalyst, gasoline-powered cars and vans without a catalytic converter, and diesel-powered cars and vans (Härkönen, 2002). Similarly, heavy-duty vehicles (HDV) are classified in the following way: diesel-fuelled lorries with a trailer, diesel-fuelled lorries without a trailer and diesel-fuelled busses, and natural gas fuelled busses (Härkönen, 2002).

The model requires also input information about the pollutants coming outside of the study area, i.e. background concentrations. The background data used in the model can be either on-site background measurements or it can be existing concentration data, e.g., in Helsinki usually from the monitoring network of the Helsinki Metropolitan Area Council (YTV).

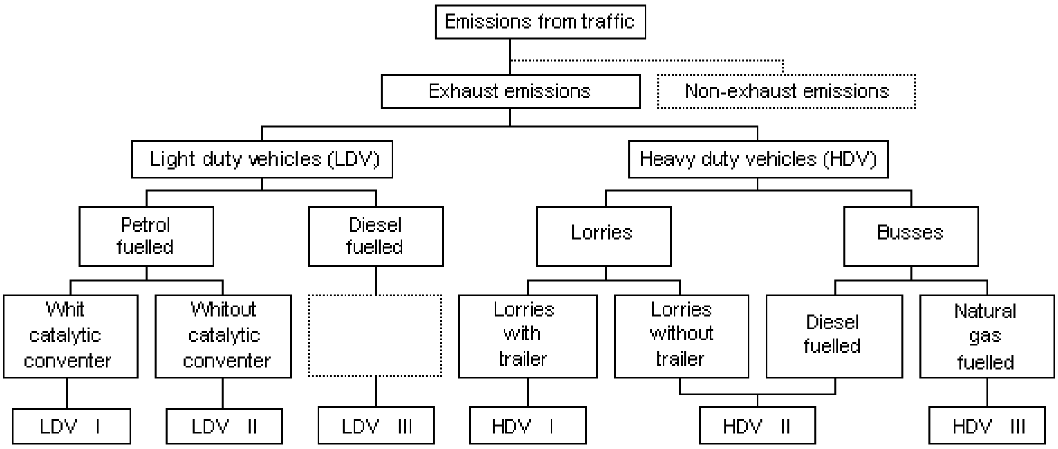

Figure 3.3: Vehicle categories used in CAR-FMI (Härkönen, 2002). Non-exhaust emissions are not included in model.

The meteorological input data for the PC version of CAR-FMI consists of hourly time series of one year. Besides the time parameters (year, month, day and hour) the data includes wind speed, measured at 10 m height from the ground surface (m/s), wind direction in synoptic coordinates (deg), inverse of Obukhov's length (1/m), mixing height (m), temperature (K), global radiation intensity (W/m2), relative humidity (%), and ambient pressure (mbar). Before the meteorological data can be used in the model CAR-FMI, the atmospheric stability parameters and mixing height have to be evaluated by the meteorological pre-processing model MPP-FMI (Karppinen et al., 1997), or by another corresponding model.

The PC-version of model CAR-FMI computes hourly concentrations for one year at each receptor point. The receptor points are located in 100 m x 100 m grid over the whole study area, apart from the reception points near the roads. Near the roads, reception points are placed denser, to the distances of 10 m, 40 m, and 90 m from the road. The model computes the concentrations for following compounds; nitrogen monoxide (NO), nitrogen dioxide (NO_2), total NO_x (as NO_2), carbon monoxide (CO), ozone (O_3) and fine particles ($PM_{2.5}$). It computes automatically the following statistical analyses; hourly maximum, 8 hourly moving averages, highest daily average, second highest daily average, highest monthly averages, yearly mean, and separately defined percentiles. The statistical analysis of the computed time series of concentrations enables a direct comparison of result with the air quality standards (Härkönen et al, 1995). The results from the model are statistically analysed and available in graphical and table format. The results can also be converted into a MIF-file, which are compatible with the Geographical Information System, MapInfo (Härkönen, 2002).

The PC version of the model CAR-FMI has Windows based graphical user interface, which has been found relatively easy to use by the city authorities and based on own testing. The good advantage of the user interface is clear and logical layout of the Edit Input–window (Figure 3.4). Also, the fact that input information can be entered in data file format is a positive feature.

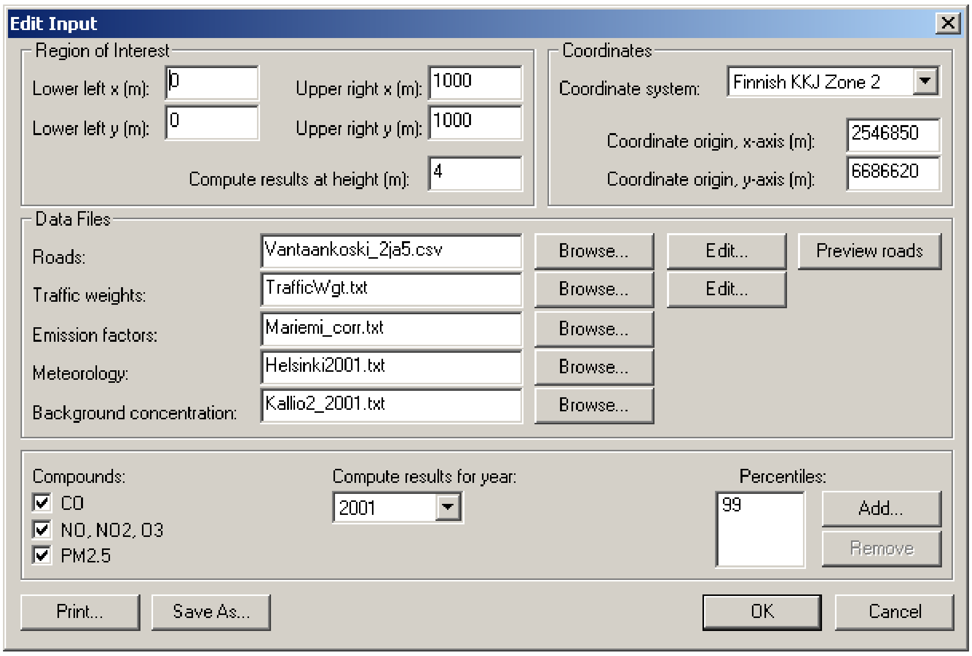

Figure 3.4: The Edit Input window of the model CAR-FMI.

The model also requires a road data file. Road data contains location of the roads (start an end points), roughness of surrounding terrain, traffic volumes, driving speeds, and vehicle distributions (see Add/Edit Road -window in Figure 3.5).

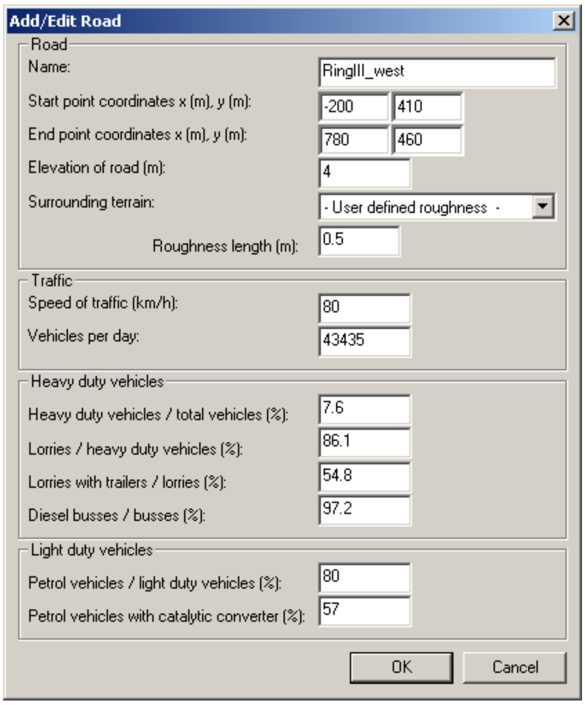

Figure 3.5: The Add/Edit Road window in the model CAR-FMI.

In PC version of CAR-FMI the background concentration data has to be one year time-series, which may cause problems if whole year data is not available. If measured background concentration data is not available, background concentration can also be the output of some background concentration model.

In case of meteorological data, the atmospheric stability parameters need to be pre-processed before they can be used in CAR-FMI model. Thus the meteorology-cal pre-processor model MPP-FMI (Karppinen et al., 1997), or comparable, has to be used. The need of pre-processing may complicate the use of the model by end users. However, the difficulties can be avoided if the pre-processed meteorology-cal data is continuously available in ready-made format.

The results from the model are statistically analysed and available in graphical and table format. Automatically analysed results enable direct comparison of computed concentrations with the air quality standards. The results can be converted to the MIF files, which are compatible with the Geographical Information System, MapInfo. In Figure 3.6, an example of the computation results at the map surface is shown. However, the output does not include the time series of the computed concentrations, which limits the analysis of computed concentrations to some extent, e.g. results cannot be analysed in the function of time or meteorology.

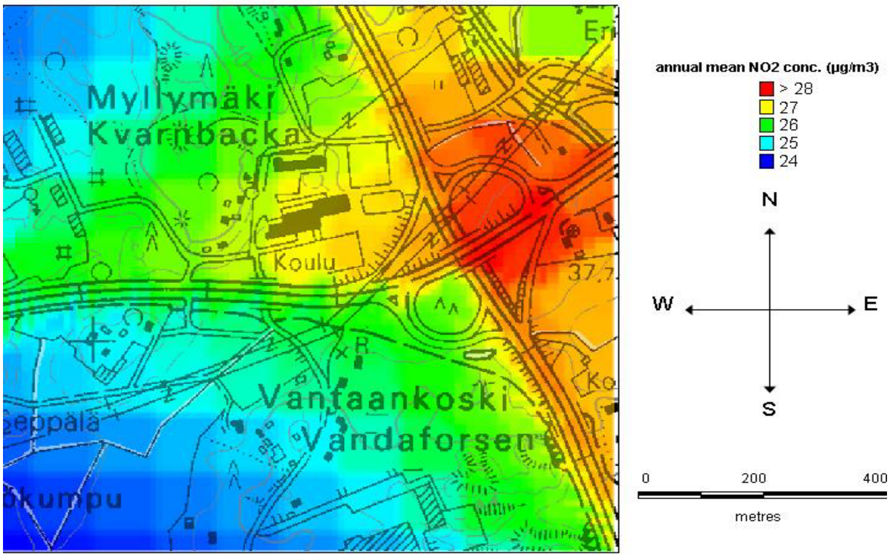

Figure 3.6: An example of the computed annual mean NO_2 concentrations at Vantaankoski area shown on GIS (MapInfo)

The graphical presentation of results is not necessarily the best format for end-users. A better format would be to show results straight on the map surface. At present, the users are first required to convert the result to MIF files, and then display the results in MapInfo. The usability of the model would be better, if results could be directly connected to the GIS. The current preview window for roads (Figure 3.7) is also not very useful, because it cannot be displayed at the same time with the result window.

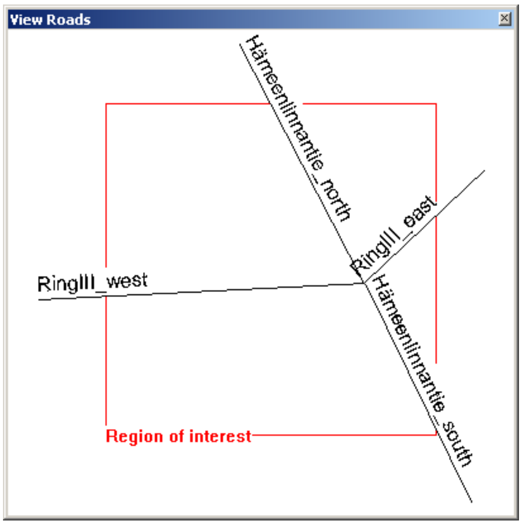

Figure 3.7: The Add/Edit Roads –window of CAR-FMI model.

The model does not yet have any tools for creating cross-sections of the certain road. Cross-section of the road is adequate when results are studied with the distance from the road. At the moment, cross-sections are only possible to make in a spreadsheet program, such as, Excel. This takes considerable long time, because user has to first find the right computation points form the tables and calculate the distance of each computation point of the cross-section from the road. The best way to create the cross-section would be to draw the location in a map surface.

3.3 Population exposure modelling

Ambient air pollution concentrations have been associated with adverse health effects. These health effects must be caused by actual exposures of affected individuals, or otherwise there would not be a causal link between the pollution and the health effects. The chain of events from emission to the health effects is depicted in Figure 3.8.

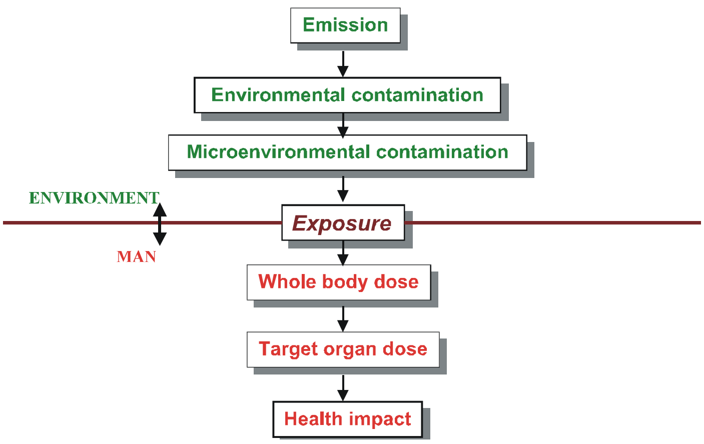

Figure 3.8: Causal chain of events from the emissions to the health impacts.

Population exposures differ from ambient air quality, because urban populations commute through the varying air quality fields through out the day and spend large fractions of their time in indoor environments, where the building envelopes modify the ambient air quality. Effective reduction of health effects must be linked to effective reductions of population exposures and thus population exposure modelling is becoming an integral part of air quality management. Population exposure models are needed to assess how the ambient air quality fields affect the population and especially susceptible population groups, like infants, elderly, and asthmatics. Population exposure models allow for a health relevant perspective to the management of ambient air quality.

Alternative population exposure modelling approaches include spatial modelling of population weighted ambient concentrations (e.g. the EXPAND model in Helsinki) and probabilistic modelling of population exposure distributions. The former is suitable for graphical presentation of variations of exposures in geographical areas as maps. This kind of spatial information can be used to target traffic and other emission interventions to the worst areas. The spatial information is also valuable in communicating air quality information to the public and giving health relevant recommendations for susceptible population groups like the asthmatics. The EXPAND model has been designed to be utilised by municipal authorities in evaluating the impacts of traffic planning and land use scenarios. For instance, this model will be used to evaluate the impacts of different scenarios in the new revision of the Transportation System Plan for the Helsinki Metropolitan Area.

Epidemiological studies have found the strongest connection between long-term exposures to fine particulates ($PM_{2.5}$) and premature mortality and other adverse health effects. These cohort studies are based on data from same cities for several years up to two decades; thus giving definition for the expression “long-term”. The risk ratio (RR) for mortality in these studies varied between 1.07 and 1.14, indicating 7-14% increase in the total mortality per an increase of 10 μgm^{-3} in the ambient long-term $PM_{2.5}$ level. In time-series studies the risk ratio for the daily variation of $PM_{2.5}$ concentrations has been estimated to be 1.015, indicating a 1.5 % increase in total mortality per 10 μgm^{-3} increase in the ambient daily $PM_{2.5}$ level. This in only one tenth of the risk connected to the long-term exposures. Intra-day peak $PM_{2.5}$ exposures have not been associated with mortality. Thus, in the case of fine particles the health perspective emphasizes estimation of daily and longer-term exposures. (WHO, 2000)

The GIS based EXPAND-modelling approach can be developed further in the future to allow for estimation of daily and longer averaging time exposures. This would require following deterministically a population sample of persons through out the day (or longer averaging time). Longer-term averages are more relevant in health perspective, but they are, however, difficult to be presented in map format.

The probabilistic modelling approach has been used and validated for estimation of the distributions of daily (24-hour) $PM_{2.5}$ exposures within the target population. In these models, the target population time-activity is described probabilistically and microenvironment concentration distributions are modelled using infiltration of the ambient pollution into indoor environments. The generated population distributions of 24-hour exposures can then be used to estimate public health risks for various end points, including increased bronchodilator use, cough, lower respiratory symptoms, change in peak expiratory flow, respiratory hospital admissions, and mortality, for which exposure-response relationships have been estimated.

The probabilistic models will be applied to estimate the distribution of 24-hour exposures during episodes lasting more than one day. The estimated distributions are readily applicable for calculating statistical estimates for the additional mortality and other health effects caused by $PM_{2.5}$ during the episodes. The model can also be used to compare the effectiveness of alternative emission and exposure reduction interventions for efficient selection of air quality management actions and prevention of adverse health impacts during the episodes. In the first phase the probabilistic model, however, will not be run as part of the operational daily air quality forecasting system. The need for this will be considered later based on the FUMAPEX results and experiences.

3.4 End-user guideline for forecasting procedure

Monitoring and modelling data on air quality and population exposures to air pollution are used in the Metropolitan area on different levels. Most air quality management actions and decisions are taken in the long run to prevent air quality problems; only a limited number of means are available for the city authorities in episode situations. Forecasting of the episode air quality, however, is important for communicating to the public and giving recommendations especially for the susceptible population groups and in setting optimal interventions for traffic and industrial emissions in the worst cases. The ultimate target of the air quality management actions, including both long-term planning and reactions to short-term episodes, is to minimise public health risks caused by population exposures to air pollution (Figure 3.9)

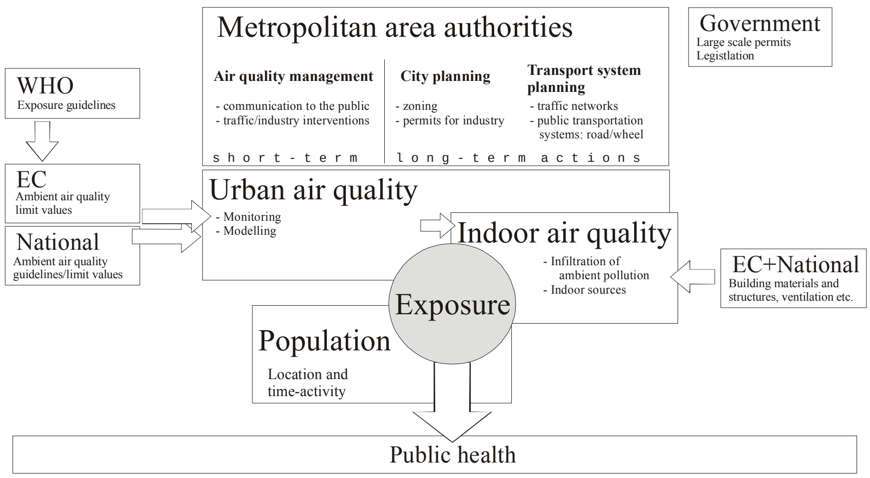

Figure 3.9: Roles of urban air quality and population exposures in air quality management and longer-term city planning actions.

The requirements of the city authorities regarding local air quality modelling have been determined by interviews in the Helsinki Metropolitan Area Council and in the Helsinki City Planning Department. A general requirement for the air quality models is that the models could be used in the analysis of typical planning cases of the city authorities. In addition, the models should be easy enough to use. This means, for instance, graphical user interfaces, good analysing tools for the results, and ready-made input data. Furthermore, the modelling and analysis of the results should not require too much time. The results are often wanted to display on a map surface. Thus, the models should also be compatible with the Geographical Information Systems (GIS).

Helsinki Metropolitan Area Council (end-user in the FUMAPEX project) has defined guidelines for the forecasting procedure in co-operation with Finnish Meteorological Institute and National Public Health Institute. Air quality is monitored by Helsinki Metropolitan Area Council. Air quality monitoring network is extensive but Helsinki Metropolitan Area Council has not any real time air quality forecasting model in use. There has been a long time modelling co-operation with Finnish Meteorological Institute. These models have been validated for this area and they have worked quite well. Helsinki Metropolitan Area Council is also an end-user in the EU/OSCAR project, which is developing air pollution modelling and presentation tools.

- Results of forecast model (weather and air quality data) have to be ready at 8 a.m. local time at the latest during weekdays (Mon-Fri). This deadline refers to local radio stations and TV, which publish the air quality index in the morning. There is no need for the forecast during weekends (Sat-Sun). Forecast is required for today and tomorrow all the year round.
- Hourly NO_2, $PM_{2.5}$, PM_{10} concentrations as well as national air pollution index (see table below) should be presented on a map. At the present we are missing $PM_{2.5}$ index but it is developed during this year (hourly based index). Weather data (temperature, wind speed and direction, mixing height, precipitation) is also needed.
- Results should be presented in a user friendly way, preferably on the internet (as a web application).
- There should be a strong co-operation with EU/OSCAR-project and system.
- Forecast models in FUMAPEX should not be based on only one commercial system; the local development and customisation of air-quality models should be fully utilized.
- Later, if the computed air quality maps (both air quality index and air pollution component maps) will be reliable enough, maps should be published in the internet.
- Emission sources which should be included are traffic, energy and heat production and long range transport; if possible also emissions from wood burning.
- Maintenance of the system (emission data, models, etc) should also be taken care of.
- Exposure results should be present as the number of people exposed in certain areas, especially in the episode situations it would be important to know the exposure of the sensitive population groups (e.g. children below 1 year).

Table 3.1: National air quality index classes for local air quality in the Helsinki Metropolitan Area (units: $\mu g/m^3$).

Index class	NO_2 (hourly)	PM_{10} (hourly)	Health effects
Good	< 40	< 20	No health effects
Satisfactory	40 - 70	20 - 70	Effects very unlikely.
Fair	70 - 150	70 -140	Effects unlikely
Poor	150 - 200	140 - 210	Adverse effects possible on sensitive individuals
Very poor	> 200	> 210	Adverse effects possible on sensitive subpopulation

3.5 References

Berkowicz, R., Hertel, O., Sørensen, N. and Michelsen, J. (1997) Modelling air pollution from traffic in urban areas, 1997. In: *Flow and dispersion through groups of obstacles*. Ed. by R. Perkins and S. Belcher. Oxford, Clarendon Press. pp. 121-141.

Bremer, P. (1993) Assessment of two methods to predict SO_2 concentrations in the Helsinki area. Helsinki, Finnish Meteorological Institute (Publications on Air Quality 15).

Bremer, P. and Valtanen, K. (1995) Air pollution predictions in Finland. In: *Proceedings of the 10th World Clean Air Congress, Espoo, Finland, May 28 - June 2, 1995. Vol. 2.* Ed. by P. Anttila et al. Helsinki, The Finnish Air Pollution Prevention Society. p. 258 (4 pages).

Eerola, K. (2000) The new operational HIRLAM at the Finnish Meteorological Institute. *HIRLAM Newsletter No. 35 April, 2000*, 36-43.

Hertel, O. and Berkowicz, R. (1989) Modelling pollution from traffic in a street canyon. Evaluation of data and model development. Roskilde, National Environmental Research Institute (NERI) (DMU LUFT-A129).

Härkönen, J., Valkonen, E., Kukkonen, J., Rantakrans, E., Jalkanen, L., Lahtinen, K. (1995) An operational dispersion model for predicting pollution from a road. *Int. J. Environ. Poll., 5,* 602-610.

Härkönen, J., Valkonen, E., Kukkonen, J., Rantakrans, E., Lehtinen, K., Karppinen, A., Jalkanen, L. (1996) A model for the dispersion of pollution from a road network. Helsinki, Finnish Meteorological Institute (Publications on air quality, 23).

Härkönen J., Walden J. and Kukkonen, J. (1997) Comparison of model predictions and measurements near a major road in an urban area. *Int. J. Environ. Poll., 8*, 761-768.

Härkönen, J., Kukkonen, J., Valkonen, E. and Karppinen, A. (1998) The influence of vehicle emission characteristics and meteorological conditions on urban NO_2 concentrations. *Int. J. Vehicle Design, 20*, 125-130.

Härkönen, J. (2002) Regulatory dispersion modelling of traffic-originated pollution. Helsinki, Yliopistopaino, Finnish Meteorological Institute (Contributions, 38).

Karppinen, A., Kukkonen, J., Nordlund, G., Rantakrans, E. and Valkama, I. (1998) A dispersion modelling system for urban air pollution. Helsinki, Finnish Meteorological Institute (Publications on Air Quality 28).

Karppinen, A, Kukkonen, J., Elolähde, T., Konttinen, M., Koskentalo, T. and Rantakrans, E. (2000) A modelling system for predicting urban air pollution. Model description and applications in the Helsinki metropolitan area. *Atmos. Environ., 34/22*, 3723-3733.

Karppinen, A., Joffre, S. and Vaajama, P. (1997) Boundary layer parameterization for Finnish regulatory dispersion models. *Int. J. Environ. Poll., 8,* 557-564.

Karppinen, A., Joffre, S. M. and Kukkonen, J. (2000) The refinement of a meteorological preprocessor for the urban environment. *Int. J. Environ. Poll., 14*, 565-572.

Kerminen, V.-M., Mäkelä, T., Ojanen, C.H., Hillamo, R.E., Vilhunen, J.K., Rantanen, L., Havers, N., von Bohlen, A. and Klowkow, D. (1997) Characterization of the particulate phase in the exhaust form a diesel car. *Environ. Sci. Techn., 31*, 1883-1889.

Kuo, H.L. (1974) Further studies of the parameterization of the influence of cumulus convection on large-scale flow. *J. Atm. Sci., 31*, 1232-1240.

Navascués, B., Ayuso, J. and Rodríguez, E. (2002) The new HIRLAM surface analysis. SRNWP/HIRLAM Workshop on Surface Processes, Turbulence and Mountains Effects. Instituto Nacional de Meteorologia, Madrid 22-24 October 2001. HIRLAM Workshop Report, January 2002, pp. 37-44.

Nikmo, J., Tuovinen, J.-P., Kukkonen, J., Valkama, I. (1997) A hybrid plume model for local-scale dispersion. Helsinki, Finnish Meteorological Institute (Publications of Air Quality No 27).

Rõõm, R. (2001) Nonhydrostatic adiabatic kernel for HIRLAM. Part I. Fundamentals of nonhydrostatic dynamics in pressure-related coordinates (HIRLAM Technical Report No. 48).

Savijärvi, H. (1990) Fast radiation parameterization schemes for mesoscale and short-range forecast models. *J. Appl. Meteor., 29*, 437-447.

Sundqvist, H., Berge, E. and Kristjánsson, J.E. (1989) Condensation and cloud parameterization studies with a mesoscale numerical weather prediction model. *Mon. Wea. Rev., 117*, 1641-1657.

van Ulden, A. and Holtslag, A. (1985) Estimation of atmospheric boundary layer parameters for diffusion applications. *J. Climate Appl. Meteor., 24*, 1196-1207.

WHO (2000): Air quality guidelines for Europe. Copenhagen, Regional Office for Europe (WHO Regional Publications, European Series, No. 91).

4 Guidelines on the output from the UAQIFS for the Castellon area, Spain

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Fundacion CEAM

4.1 Description of the current UAQIFS

A daily procedure to forecast the levels of surface ozone for the Comunidad Valenciana (C.V.) over a regional scale has been operational since the year 2000 (PREVIOZONO Program). Every year, this program has been carried out between the months of April and September, in concurrence with the highest concentrations of this pollutant within the region.

C.E.A.M. Foundation has been entrusted with the responsibilities of the PREVIOZONO program by the Direccion General de Educacion y Calidad Ambiental (D.G.E.C.A.) (End-User). This entity belongs to the regional government and is in charge of the regional air quality management. The PREVIOZONO program has been created to cover the legal requirements linked to the European air quality guidelines (Directive 96/62/EC and derivatives), with special emphasis on informing and warning the population about cases of high ozone concentration. The D.G.E.C.A. also runs the *Red Automatica de Vigilancia de la Calidad del Aire* (R.A.V.C.A.) (Automatic Air Quality Network) in the C.V. This network performs continuous measurements of air pollutants and meteorological variables, such as SO_2, NO_x, CO, O_3, PM10, wind direction, wind speed, ambient temperature, radiation, and precipitation, at many sites within the C.V. (a total of 33 sites are included). C.E.A.M. has been collaborating with the development and optimisation of this network by improving its spatial coverage, implementing the legal guidelines related to the directive 96/62/EC, and interpreting the measurements. The information that this network provides is available to the C.E.A.M. almost on real time, along with the meteorological analysis maps and the HIRLAM model predictions provided by the Instituto Nacional de Meteorologia (I.N.M.). These data constitute the basic information and starting point to perform a daily ozone forecast. In order to assure public access to the information, the forecast is posted over the internet (http://www.cma.gva.es/ftp/ozono/html/index.html).

The information released in this daily forecast is based on the expertise of CEAM's staff that has been working on pollutant dynamics affecting the region for summer and springtime conditions. These dynamic conditions, including their influence over the spatial distribution and the levels of ozone in the Iberian Peninsula and particularly over the C.V., have been widely described under European research projects such as MECAPIP and RECAPMA (Millan M., 1992, 1997). During the spring and summer months, very stable atmospheric conditions associated with anticyclonic circulations tend to dominate over the C.V. Moreover, a weak pressure gradient at a synoptic scale favours the development of a regional scale wind circulation (sea breeze), being frequently reinforced by the formation of a thermal low over the centre of the Iberian Peninsula. These circulations, very circumscribed by the topography, drive the air mass transport from the coastline, where the emissions are located, to the interior giving rise to a distinctive dynamic pattern. The spatial and temporal distribution of the pollutants, as a consequence of this dynamic feature, has been confirmed by the R.A.V.C.A. of the C.V. (Millan M., 2000).

Until now, the ozone forecast relies on the staff expertise along with a statistical analysis based on the R.A.V.C.A. of the CV dataset (see section "*Statistical analysis and forecast*"). However, the forecast procedure lacks an objective method to estimate the pollutant concentrations. This objective methodology, consisting of a numerical module encompassing a meteorological and a photochemical model, would generate ozone concentration fields for the region. This model output would be in turn interpreted by the expert staff as an intermediate step for the formulation of the daily forecast. Within the context of the FUMAPEX project, such objective module will be developed and applied to one of the scenarios that were already scrutinized for the C.V. covering the urban/industrial area of Castellon and the rural area affected by its emissions. Therefore, the incorporation of this module to a daily procedure similar to PREVIOZONO will constitute the required UAQIF.

Finally, applying the UAQIF for each of the different scenarios covering the rest of the C.V. territory will complete the tool that will be equivalent to the current PREVIOZONO as required by the D.G.E.C.A. This will not be carried out within the context of the FUMAPEX project.

4.1.1 Forecast procedure

The PREVIOZONO program basically consists of the daily release of a bulletin at 8:00 PM between the months of April and September, from Monday to Sunday, which includes the forecasted ozone levels for the CV. This report comprises a page (pdf format) that is uploaded to the internet server of the regional government and has three basic parts. Namely,

1. *Analysis of the current situation*: Daily averaged values and hourly averaged maximum concentrations overlapped on a CV map showing the measurement points. The interpretation of these values is included in a text box. This explanation is based on the data obtained from the RAVCA of the CV and the analysis of synoptic meteorological maps generated by the HIRLAM model.
2. *Forecast for the next day*: Departing from the analysis of the current ozone levels and the meteorological forecast obtained from the HIRLAM model, a qualitative forecast is performed. This prediction includes a discussion on the tendency that the levels of ozone will follow at different areas within the CV.
3. *Recommendations to the public* when high levels of ozone are expected.

The preparation of the daily report begins at 6:00 PM following a procedure that is completed in about two hours, making this bulletin available on the internet at 8:00 PM. Each watch period lasts 24 hours that starts at 4:00 PM UTC on the day in which the report is released. This schedule arises indeed as an agreement with the DGECA (end-user) needs. The end-user requires the forecast to be available soon enough to warn the general public in cases when the ozone levels are expected to exceed the warning threshold. Also, the forecast information should be made available to the interested media for further distribution.

The forecast procedure consists of three stages (see the schematic below).

ACQUISITION PHASE

Weather service connection **R.A.V.C.A. of the C.V. database connection**

- Analysis maps for latest 24 hours
- Forecast maps for the next 24 hours
- R.A.V.C.A. of the C.V. data acquisition

Meteosat images

CALCULATION AND ANALYSIS PHASE

Meteorological analysis and forecast for the C.V. ozone

- Analysis of the meteorological situation for the last 24 hours.
- Evolution of the meteorological scenario for the next 24 hours

Statistical, spatial, and temporal analysis of the concentrations.

- Data validation.
- Statistical analysis.
- Graphical representation of the evolution, tendencies, and increments in the ozone levels.
- Analysis of ozone concentrations.
- Estimation of the most probable evolution of the ozone levels.

WRITING AND DISTRIBUTION PHASE

Writing the report for the next day.

- Include the 24-hour averages and hourly maximums within the report.
- Write the analysis for the last 24 hours, the forecast evolution for the next 24 hours, and, if necessary, the recommendations to the general public.

Distribution of the daily bulletin

- Uploading the report on the Conselleria (government) web page.
- Warning, if necessary, the Centro de Emergencias de la Generalitat Valenciana (Emergency Center of the Valencian Government)

The various stages in the forecast procedure thus consists of:

- Data acquisition form RAVCA of the CV: program PDW (end-user).
- Data preprocessing and visualization of the complete time series of pollutants and meteorological variables for each measurement point: computer program developed in C (CEAM).
- Graphical representation, measurement validation, and statistical calculation of ozone levels: computer program developed in Visual Basic (CEAM) run within EXCEL spreadsheet framework.
- Report preparation using a predetermined form (see an example in the next page): own program (CEAM) run within data base manager (ACCESS) framework.

4.2 Statistical analysis and forecast

The analysis of a series of ozone data corresponding to the area of Castellon and its surroundings shows that high concentration levels of this pollutant respond to a characteristic pattern. This feature allows the prediction of ozone to be with an acceptable level of confidence. Since 1997, the ozone pattern has been repeating itself in 21 of 23 of the registered exceedances in the CV.

The main features of this analysis are described below:

- The exceedances take place in the spring and summer months under the influence of mesoscale anticyclonic circulations and stable atmospheric conditions.
- There is a gradual increase in the maximum ozone concentrations between each consecutive days (recharging period). This occurs when the above-mentioned meteorological conditions are maintained.
- These time periods cover about 30% of the days between the months of April and September (with a maximum in July covering 50% of the days) and they last between 3 to 8 days (4-5-day average).
- The ozone recharging periods generally affect all the forecasting area, from the coast to the interior. Not all of these cycles give rise to an ozone exceedance of the 180 $\mu g/m^3$ threshold, however they usually produce the ozone levels to surpass the objective value for human health protection (120 $\mu g/m^3$ over an 8-hour average).
- When an exceedance takes place, it rarely surpasses 190 $\mu g/m^3$ and it does not last more than 2 or 3 hours. These high levels of ozone are generally observed at coastal sites after 2:00 PM and at inland stations with a delay of 1 or 2 hours with respect to the coastal locations. This delay is associated to the sea breeze transport of pollutants and their photochemical transformations.

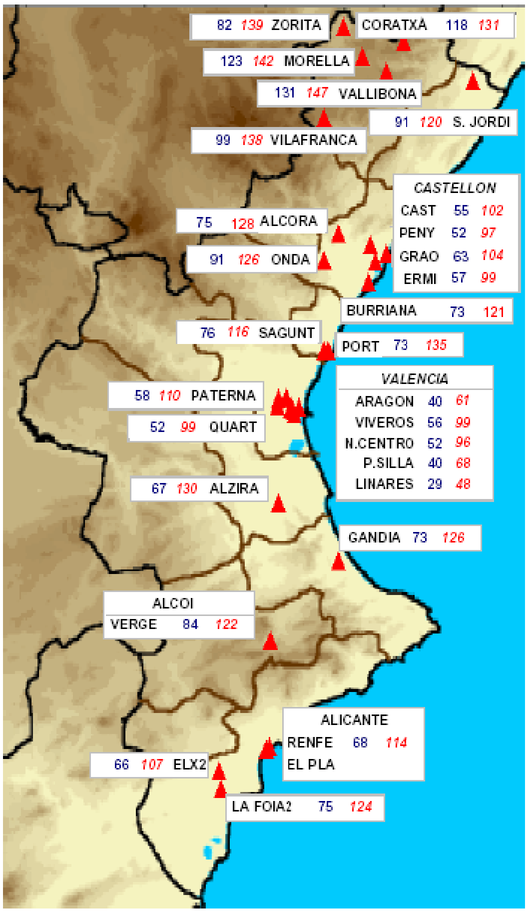
GENERALITAT VALENCIANA
CONSELLERIA DE MEDIO AMBIENTE

CEAM

INFORME DIARIO SOBRE NIVELES DE OZONO EN LA COMUNIDAD VALENCIA

Válido para el viernes, 30 de mayo de 2003

Concentraciones de O3 (µg/m3) registradas en la Red de Vigilancia de la Calidad del Aire



LEYENDA: ESTACION md *mmh*

md Promedio entre las 18h del 28/05/03 y las 18h del 29/05/03
mmh Máximo de los promedios horarios entre las 00h y las 18h del 29/05/03

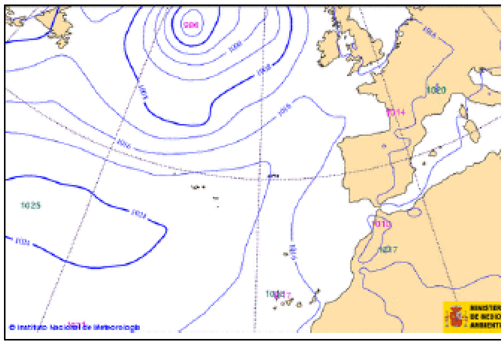
Valor del umbral de información a la población: 180 µg/m3 (Promedio horario)

(Directiva 92/72/CEE - Real Decreto 1494/95)

ANÁLISIS: La pasada jornada continuó marcada por condiciones de estab como consecuencia de las altas presiones que dominan sobre toda la península tanto en superficie como en las capas altas. En la Comunidad Valenciana los cielos permanecieron despejados o poco nubosos y las temperaturas siguieron con la tendencia al ascenso. Las circulaciones de se establecieron sobre todo el territorio de la C.V. apoyadas durante el día la circulación general de componente SE.

Bajo estas condiciones meteorológicas los niveles de ozono evolucionar siguiendo los característicos ciclos diarios con mínimos nocturnos y máxin partir de mediodía. Respecto a la jornada precedente no se registraron variaciones de consideración, aunque la tendencia general fue al ligero incremento de las concentraciones en el interior, y sin variaciones o con disminuciones muy ligeras en emplazamientos de costa.

Situación meteorológica prevista para hoy :



Fuente: www.knmi.nl

Evolución esperable de los niveles :

La situación meteorológica apenas experimentará variaciones. La penins continuará bajo condiciones anticiclónicas tanto en superficie como en al favoreciendo de nuevo cielos predominantemente despejados y temperat sin cambios o en suave aumento. El escaso gradiente de presiones en superficie favorecerá el amplio desarrollo del sistema de brisas que afect la práctica totalidad del territorio.

La continuidad en las condiciones atmosféricas se traducirá también er continuidad en la evolución de los niveles de ozono sin que se prevean variaciones sustanciales. En todo caso la tendencia continuará siendo al suave aumento de las concentraciones especialmente en el interior. Dad niveles actuales, ligeramente por encima de los valores promedio históric del mes de Mayo (en parte debido a que estamos entrando prácticament el mes de Junio), estos niveles se mantendrán relativamente alejados de umbrales legales de referencia, sin que se prevea en ningún caso la superación de estos.

RECOMENDACIONES: No se considera necesario adoptar ninguna medida especial

PREVISIÓN: Continuidad en las condiciones anticiclónicas con cielos despejados y temperaturas sin cambios o en suave aumento. Los niveles ozono no mostrarán cambios sustanciales, y en todo caso se espera un lig aumento de las concentraciones especialmente en el interior. No se prevé ningún caso la superación de los umbrales legales de referencia.

The following Figures illustrate some of these aspects. The calculated values have been filtered only for measurements corresponding to recharging periods.

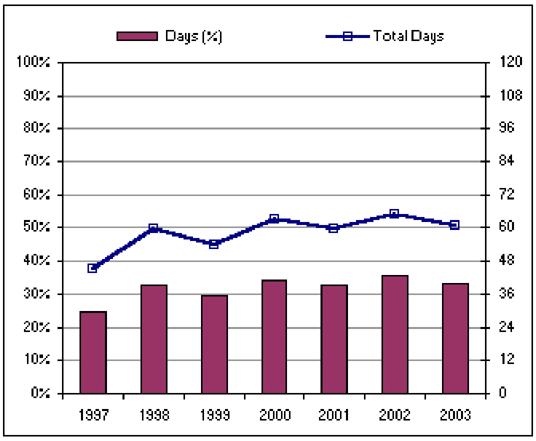


Figure 4.1: Interannual evolution of the number of days included in the recharging periods.

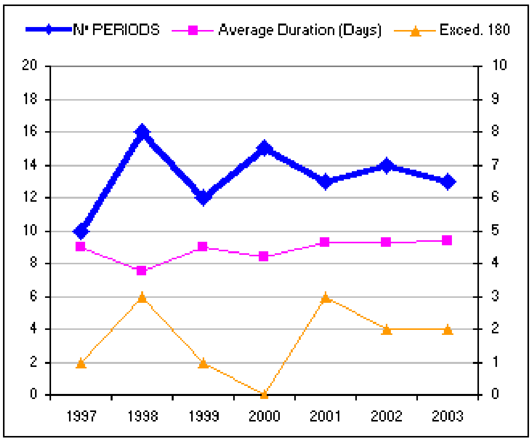


Figure 4.2: Interannual evolution of the number of recharging periods, average duration (number of days) of the recharging periods, and number of exceedances of the 180 $\mu g/m^3$.

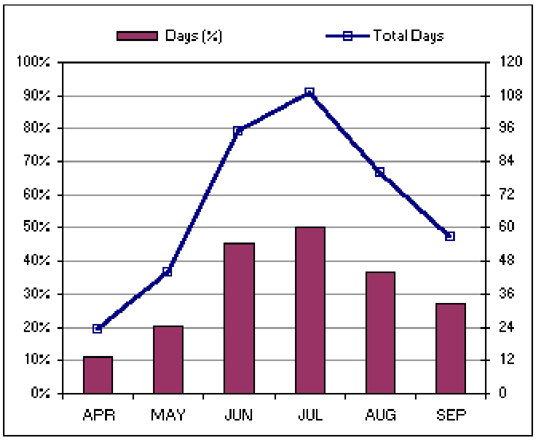


Figure 4.3: Evolution of the number of days included in the recharging periods between April and September.

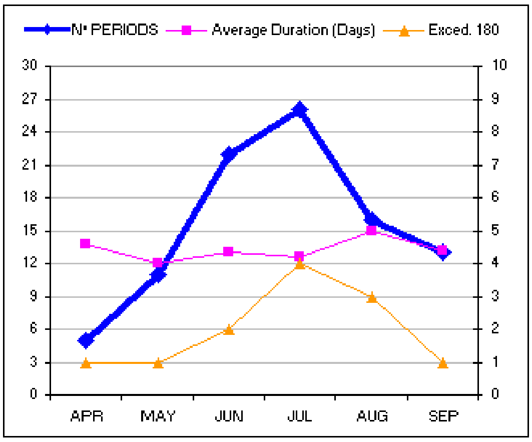


Figure 4.4: Evolution of the number of recharging periods, average duration (number of days) of the recharging periods, and number of exceedances of the 180 $\mu g/m^3$, between April and September.

4.3 Improved UAQUIF to be developed

The required UAQUIF, to be developed within the FUMAPEX project, consists of two models: a photochemical model (CAMx) and a meso-meteorological model (RAMS). Meteorological fields produced by the RAMS model along with primary pollutant emissions data will be coupled to the CAMx photochemical simulation.

The photochemical model will be run for a coarse grid covering the Iberian Peninsula and a finer grid including the forecast target area. Emission inventories based on EMEP data for the Iberian Peninsula will serve as a basis for the photochemical model to calculate the pollutant background concentrations. These pollutant levels will in turn be used as boundary conditions for the finer grid. Furthermore, detailed emission inventory data and nested meteorological fields from RAMS at the fine grid will be used to estimate the ozone levels for the Castellon area. The model output would be in turn interpreted by the expert staff as an intermediate step for the formulation of the daily forecast.

4.4 Output requirements for the UAQIFs (End-user guidelines for forecasting procedure)

- Calendar and schedule of the daily report: at 8:00 PM, April to September, from Monday to Sunday.
- Report accessible to the general public through the internet. This report can be reformatted according to the media needs.
- Clear and understandable information for the general public.
- Minimum information included in the report:
    - Evaluation of the ozone levels for the last reported period (today).
    - Forecast of the evolution of the ozone levels for the next reporting period (tomorrow).
    - General information about the origin and effects of ozone in the troposphere.
- Forecast format:
    - Use of a scale that relies on an objective value based on human health protection and general population information and warning thresholds (directive 2002/3/EC). It has also been proposed the use of an Air Quality Index (based on ozone only) defined by the end-user.
    - Assign a scale value to each of the areas delimited on the zonification map. We propose to show a map subdivided into the delimited zones each one with a colour code associated to the value of the index.
- In case the ozone concentrations exceed the 180 µg/m3 value the CV emergency centre will be warned and the following information will be submitted
    - Delimitation of the affected area.
    - Estimated hour and duration of the exceedance.
    - Forecast of the ozone levels evolution after the exceedance took place.
    - Recommendation for the general public.

4.5 References

Millán, M.M. and Artiñano, B. (1992) Mesometeorological cycles of air pollution in the Iberian Peninsula. Brussels, Commission of the European Communities.

Millán, M.M., Salvador, R., Mantilla, E. and Artiñano, B. (1996) Meteorology and photochemical air pollution in southern Europe: experimental results from EC research projects. *Atmos. Environ., 30,* 1909-1924.

Millán, M.M., Salvador, R., Mantilla, E. and Kallos, G. (1997) Photooxidant dynamics in the Mediterranean basin in summer: results from European research projects. *J. Geophys. Res., 102,* 8811-8823.

Millán, M.M., Mantilla, E., Salvador, R., Carratalá, A., Sanz, M. J., Alonso, L., Gangoiti, G. and Navazo, M. (2000) Ozone cycles in the Western Mediterranean Basin: interpretation of monitoring data in complex coastal terrain. *J. Appl. Meteorol., 39,* 487-508.

Millán, M. M. (2002) Ozone dynamics in the Mediterranean basin. A collection of scientific papers resulting from the MECAPIP, RECAPMA and SECAP Projects. Brussels, European Commission (Air Pollution Research Report 78).

5 Guidelines on the output from the UAQIFS for the city of Turin, Italy

Authors: Sandro Finardi [(1)], Roberta De Maria [(2)], Francesco Lollobrigida [(2)], Guiseppe Calori [(1)], Monica Clemente [(2)], Cinzia Cascone [(2)]

[(1)] ARIANET Consulting
[(2)] ARPAP - Environmental Protection Agency of Piedmont

The project of the UAQIFS presently described is intended to forecast pollutants such as suspended particulate matter PM_{10}, nitrogen dioxide and ozone in order to give to the local administrations and the population the information required by the present legislation applied in Italy. The above mentioned pollutants are the most critical in the city of Turin and its surroundings, as it has been pointed out by the data recorded at the monitoring stations and by the air quality assessment carried out by A.R.P.A.P. during year 2002; sulphide dioxide and carbon monoxide show instead quite low levels and, SO_2 in particular doesn't seem to represent any longer a problem in the metropolitan area.

In section 5.1 it is reported a brief review of the actions concerning the air quality that the local administrations in Piedmont are undertaking, with a short description of the present Qualitative Operational Information System applied. Section 5.2 gives a description of the major features of the UAQIFS under development. In section 5.3 the desired output from the forecasting system, as required by the end-users, is defined.

5.1 Description of the presently applied Operational Information System for Turin

The Piedmont Region, following the Italian legislation D. Lgs. 351/1999 and D.M. 60/2002 – which accomplish, respectively, the European directive 96/62/CE and its daughter directives 99/30/CE and 00/69/CE – and according to the air quality assessment, has assigned the municipalities of the region to different zones (according to the criteria outlined in the above mentioned laws) and has defined the guidelines for the so-called "Action Plans" that the Province have to determine.

The Province of Turin, that is the local authority responsible for the management of risk situations, and the municipalities that record the higher pollutant levels in the Province have then elaborated the "Operative Intervention Plans" that must be adopted in case of pollution episodes. The plan foresees *long term actions* and *temporary actions*; the first are mainly intended to reduce the emissions of pollutants such as particulate matter (PM_{10}), nitrogen dioxide, benzene and carbon monoxide, while the second are defined in case of exceedances of the alarm limit for NO_2 and SO_2.

Following the results of the air quality assessment, the municipalities in which the traffic represents the first source of pollution have been pointed out; consequently, one of the long term actions that these (the city of Turin and other 17 municipalities located in its surroundings) have to carry out is the traffic limitation of the non-catalytic vehicles during the period from the 1st of October to the 31st of March on every Wednesday and Thursday between 7:30 and 19:00.

According to the previous reasons, the target domain of the UAQIFS for the city of Turin has been chosen to support the actions of the Provincial authority and the municipalities, to predict the effectiveness of the measures taken and to suggest, if necessary, the need of new actions in order to avoid the occurrence of heavy pollution episodes leading to exceedances of the alarm limit for NO_2 and SO_2.

The Air Quality Index for the Turin metropolitan area – that includes 12 municipalities – is presently under test and this information is going to be delivered to the public in a few weeks; at present the AQI refers to the preceding day (as it is calculated with the data recorded at the monitoring stations) and it is completed by a qualitative forecast for the day of delivery of the information and the day ahead. In Figure 5.1 an example of the daily information concerning the AQI that is going to be published on Internet is reported.

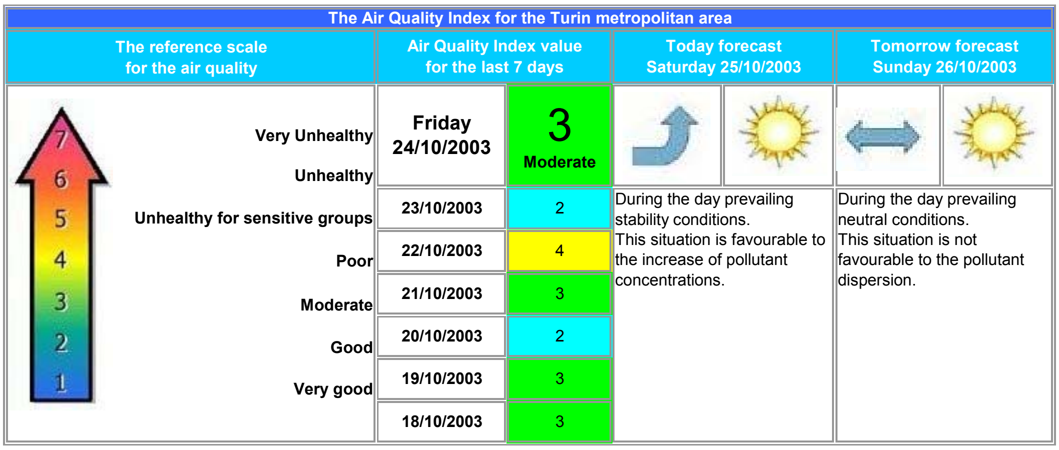


Figure 5.1: Example of daily information concerning the AQI for the Turin metropolitan area (the present forecast is made in Italian).

The UAQIFS, that is being developed, is also intended to give support to the AQI determination in order to give quantitative predictions of the index itself.

During the summer season high ozone levels affect the Province of Turin and the whole Region; A.R.P.A.P. actually provides daily qualitative forecasts of the ozone concentration levels - based on the previously measured concentrations and on the weather forecasts - and gives advices to the population in order to minimize the risks for the human health. The following table shows the warnings to the population referring to the four conventional ozone levels.

Table 5.1: Warnings corresponding to the conventional concentration levels.

LEVEL 0	No warnings
LEVEL 1	Warnings for more sensitive groups
LEVEL 2	Warnings for moderate sensitive groups
LEVEL 3	Warnings for the whole population

5.2 Description UAQIFS under development for Turin

The UAQIFS that is being built in Torino is based on the prognostic non-hydrostatic Meteorological model RAMS (Pielke et al., 1992; Cotton et al., 2003) which will downscale results of a Numerical Weather Prediction model to the urban scale and drive ARIANET's chemistry transport model FARM (Silibello and Calori, 2003). The system takes into account local terrain morphology, land cover features and detailed emissions inventories made available by Piemonte Regional Authority. The modelling system should be able to forecast the concentrations of all the pollutants considered by the EU and Italian air quality legislation and covered by the main air quality monitoring, including SO_2, NO_2, CO, PM_{10}, O_3 and Benzene. The attention is being focused on the pollutants originating exceedances of the concentration limits and causing the major environmental and public health concern NO_2, PM_{10}, O_3. The target resolution of the urban area will be of the order of one kilometre, enabling the resolution of the main features of the urban area, without entering the street canyon scale. The Urban Air Pollution modelling system will be applied simultaneously to the city of Torino and to the whole Piemonte Region. The domain nesting approach, applied to both meteorological and air quality models, allows to better take into account the effect of sources located outside the urban target domain, and to describe air pollution processes dominated by scales larger than the city scale, like photochemical smog.

The forecasting modelling system is aimed to join the scientific reliability of the system with the end user goals, together with an upgradeable system architecture and the possible exportability to different target cities. The architecture of the computational system should be as modular as possible, limiting models inter-dependence, and allowing system upgrades either upgrading or substituting single modules like models or interfaces. Results production visualisation and management should be user oriented to facilitate their presentation interpretation and comparison with the present legislation.

In the following sections is presented a preliminary version of the envisaged simulation system. The desired features will be gradually implement and verified throughout the whole project life cycle.

5.2.1 UAQIFS architecture

The system is built around four main components (see Figure 5.2):

- an emissions pre-processing system;
- a prognostic non-hydrostatic meteorological model;
- an Eulerian atmospheric chemistry model;
- an interface module connecting meteorological and air quality models.

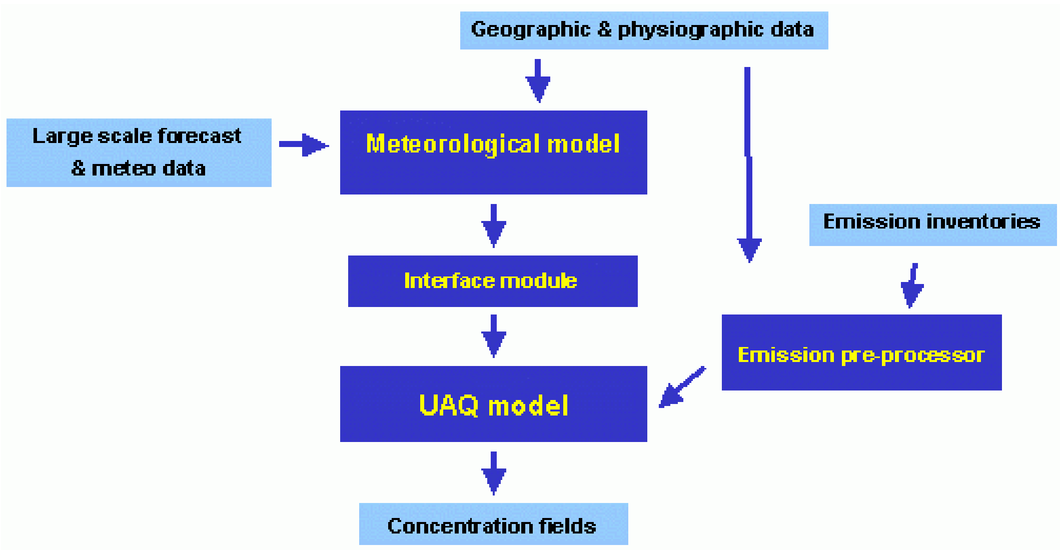


Figure 5.2: Turin City UAQIFS architecture.

Three nested domains are considered, to describe atmospheric motions, sources influence and air pollution processes at all the different scales potentially affecting the target urban area:

- a "background" domain with 16 km horizontal resolution (green rectangle in Figure 5.3);
- a regional domain, including all Piemonte, with 4 km resolution (blue rectangle in Figure 5.3);
- a metropolitan domain, focused on the city of Turin, with 1 km resolution (red rectangle in Figure 5.3).

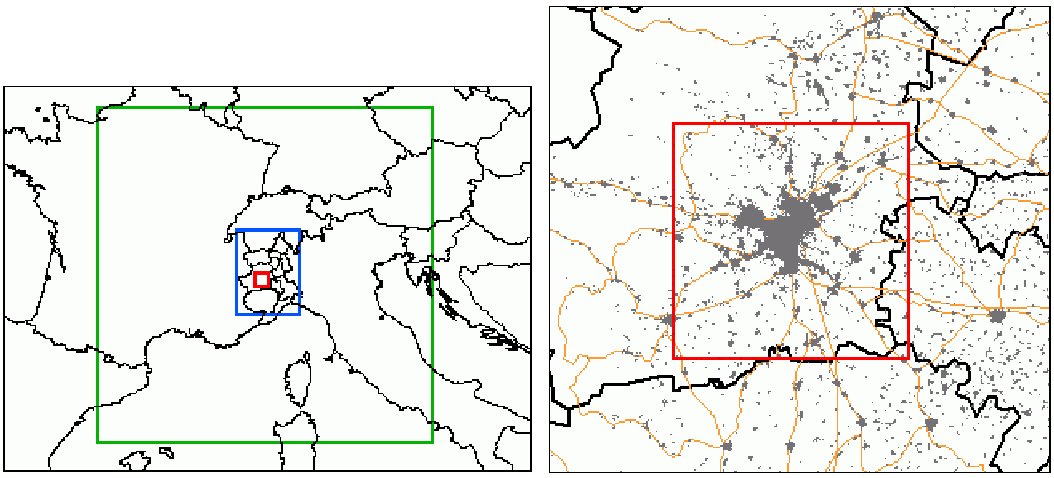


Figure 5.3: Turin City UAQIFS nested computation domains (left). The major road network and urbanised area are depicted on the metropolitan area domain (right).

5.2.2 Emission treatment

Input emissions for the three nested domains are prepared from data coming from different inventories: the high-resolution inventory of Piemonte Region, the national Italian inventory and the European scale EMEP inventory. Hourly emissions of the desired species are then estimated through the use of a pre-processing system allowing a flexible space disaggregation, time modulation and NMVOC (non-methanic hydrocarbon) speciation of inventory data related to point, line and area sources. Different thematic data (e.g. CORINE Land Cover, built-up areas, road networks), activity-specific modulation patterns and speciation profiles are used during the process. NMVOC are lumped according to the needs of the chemical mechanism used by the model.

For FUMAPEX test cases, two types of sources have been considered: the major point sources insisting on the region (several hundreds), and area sources, including all other emissions scattered on the territory. Figure 5.4 illustrates the estimated hourly CO diffuse emission fields, reconstructed on the three simulation domains, at 8 UTC of 20 July 1999.

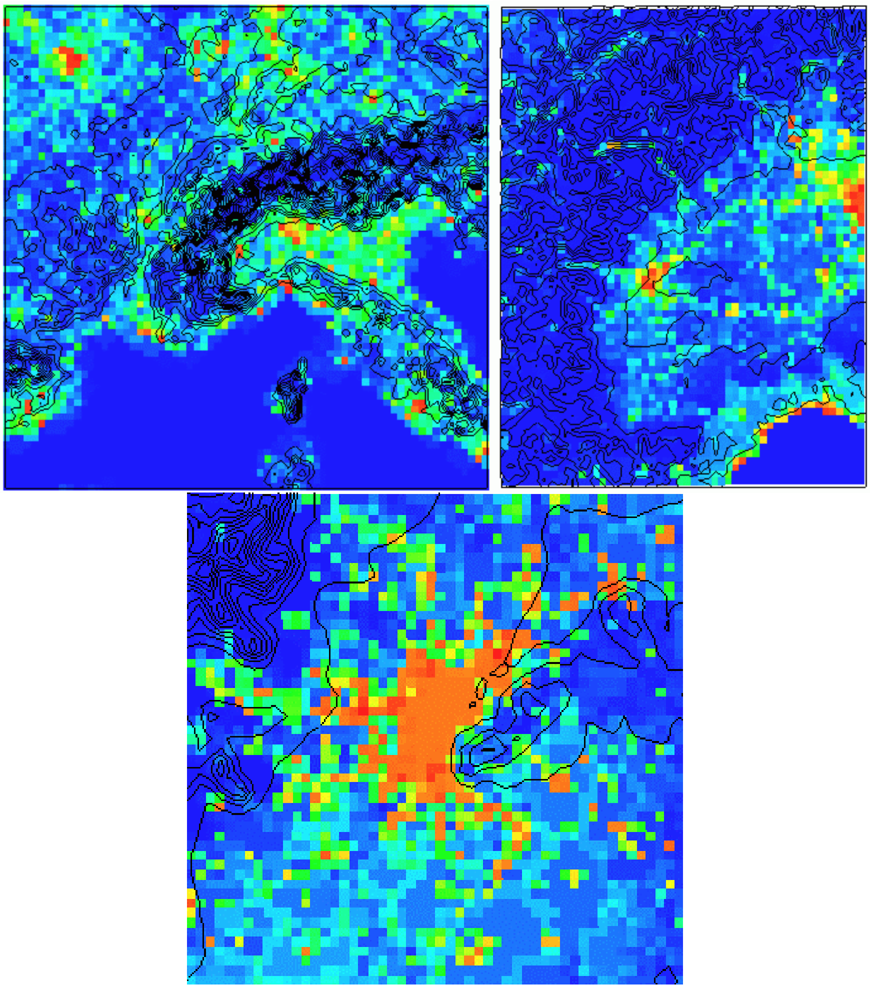


Figure 5.4: CO diffuse emission hourly fields, reconstructed for the selected summer episode on the three simulation domains, at 8 UTC of 20 July 1999.

5.2.3 The Meteorological model RAMS

RAMS, the Regional Atmospheric Modelling System (Walko and Tremback, 2002), is a numerical code for simulating and forecasting meteorological phenomena. The atmospheric model is constructed around the full set of non-hydrostatic, compressible equations that atmospheric dynamics and thermodynamics, plus conservation equations for scalar quantities such as water vapour and liquid and ice hydrometeor mixing ratios. These equations are supplemented with parameterisations for turbulent diffusion, solar and terrestrial radiation, moist processes including the formation and interaction of clouds and precipitating liquid and ice hydrometeors, kinematic effects of terrain, cumulus convection, and sensible and latent heat exchange between the atmosphere and the surface, which consists of multiple soil layers, vegetation, snow cover, canopy air, and surface water. Two-way interactive grid nesting in RAMS allows local fine mesh grids to resolve small-scale atmospheric systems, while simultaneously modelling the large-scale environment of the systems on a coarser grid.

For the Turin UAQIFS the meteorological model RAMS is used to downscale the currently available weather forecast to a scale and resolution suitable to describe local topography, surface cover and urban area effects on the atmospheric circulation. This objective is obtained through the application of a 3 level grid nesting. Due to the peculiar geographic location of Turin city, at the western limit of the Po River valley, clustered between the Alps and a hilly region, a proper meteorological downscaling is important to obtain a reliable description of local and urban scale meteorology.

Initial and boundary conditions to the RAMS simulations can be provided by any larger scale NWP model. At the moment the development activities are based on the ECMWF Forecast and Analyses fields and on local measurements for lower layers initialisation. In the near future high resolution driving fields from the Limited Area Model LAMI (the Italian version of Lokal Modell) will be made available from the Regional Meteorological Service of Regione Piemonte. These meteorological fields will be considered both for direct use and to drive RAMS simulations.

The RAMS configuration that is being tested is resumed in Table 5.2. The reported data correspond to the computational domains depicted in Figure 5.3., consisting of three nested grids having horizontal resolutions respectively of 16, 4 and 1 km.

Table 5.2:RAMS computational domain features.

Computational grid	**1**	**2**	**3**
Horizontal resolution	16 km	4 km	1 km
Grid points (nx*ny*nz)	75x75x35	58x74x35	54x54x35
Δt	30 sec	15 sec	5 sec
Minimum Δz	50 m	50 m	50 m
Domain top	23 km	23 km	23 km

Topography and land use of the urban area of Turin are shown in Figure 5.5 and Figure 5.6. The topographic data have been derived from the U. S. Geological Survey (USGS) global data sets called GTOPO30, having a space resolution of 30”. The land use data have been obtained from the European dataset called CORINE land cover, having a resolution of 250m.

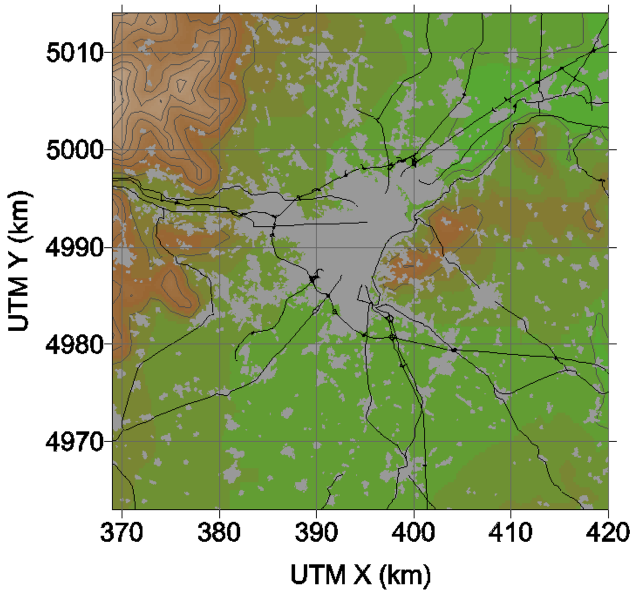


Figure 5.5: Topography of the RAMS inner domain covering the Turin urban area. Urbanised areas are indicated in grey colour, black lines identify the major extra urban road network.

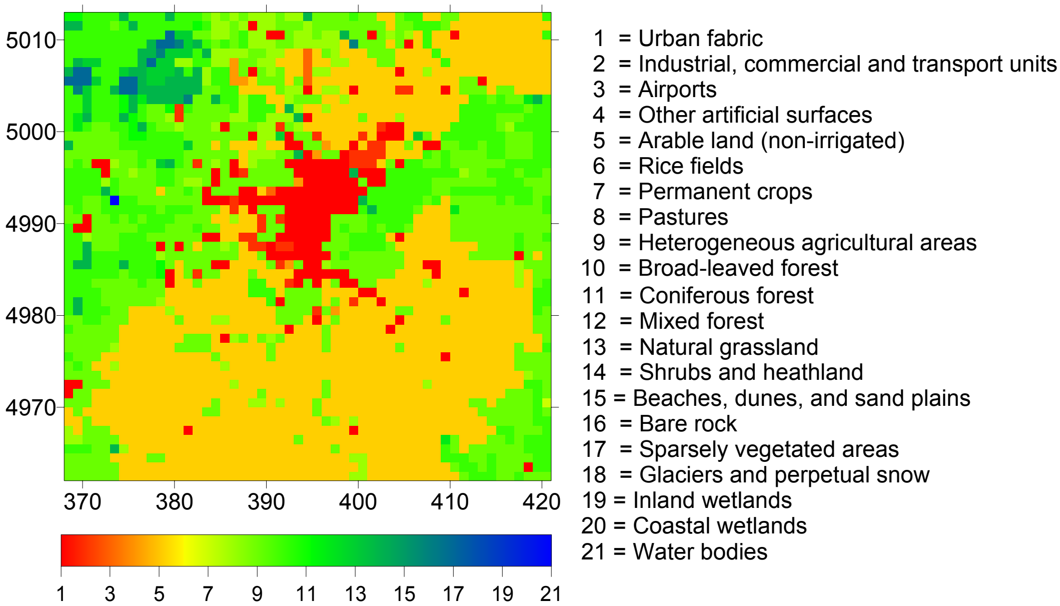


Figure 5.6: Land use of the RAMS inner domain covering the Turin urban area. Information elaborated from CORINE land cover data base.

5.2.4 The meteorology-air quality interface

A meteorological pre-processor interface processes the meteorological model RAMS output to meet the input requirements of the Eulerian chemistry transport model (Silibello et al., 2001). The interface module performs the following operations:

- *Space interpolation:* The pre-processor has a "generalised" approach. No relation is assumed between meteorological and air quality grids. The meteorological variables are supposed to be defined on sparse horizontal points, defined by their geographic co-ordinates. Interpolation is performed both in horizontal and in vertical.

- *Change of co-ordinate grid system:*
  - Horizontally: from rotated polar stereographic projection in RAMS to UTM in FARM;
  - Vertically: From a normalised sigma_z in RAMS to a pure terrain following co-ordinate system in FARM.

- *Meteorological input variables transferred form RAMS:*
  - 3-D: Horizontal wind components, temperature, relative humidity, horizontal and vertical diffusivities;
  - 2-D: Precipitation, cloud cover, surface pressure

- *Supplementary external variables/fields:*
  - 2-D: Topography, land-use classification

The vertical velocity is recalculated from the gridded horizontal wind field applying the continuity equation to obtain a mass consistent wind field.

For some turbulence describing variables parameterisations (e.g. horizontal/ vertical diffusivities or dry deposition velocities) both the modelled values, provided by the meteorological model, and diagnostically estimated values can be employed.

5.2.5 The chemistry transport model FARM

FARM (Flexible Air quality Regional Model) is a three-dimensional Eulerian model that accounts for the transport, chemical conversion and deposition of atmospheric pollutants. The code has been derived from STEM (Centre for Global and Regional Environmental Research, Univ. of Iowa; Carmichael et al., 1986; Chang et al., 1990; Carmichael et al., 1991; Carmichael et al., 1998), and its major features include:

- emission of pollutants from area and point sources, with plume rise calculation and mass assignment to vertical grid cells;
- three-dimensional transport by advection and turbulent diffusion;
- simple or detailed cloud module;
- transformation of chemical species by gas-phase chemistry, with flexible mechanism configuration;
- aerosol modelling through modal approach;
- dry removal of pollutants dependent on local meteorology and land-use;

- wet removal through precipitation scavenging processes;
- possibility of one- or two-way nesting with an arbitrary number of computational grids;
- interface with a complete modelling system for multiscale air quality simulations.

The preliminary test has been made using the SAPRC90 chemical mechanism and two-way nesting on the three simulation grids.

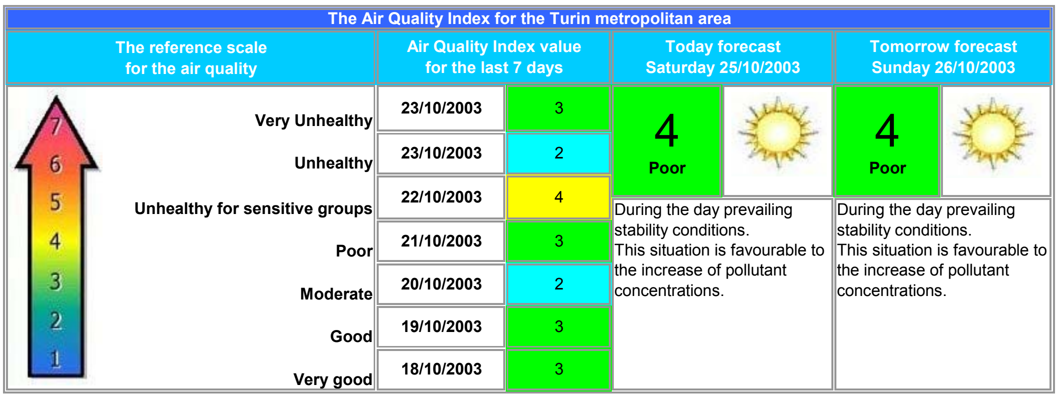
Examples of test simulation results are available at the following web address: http://www.aria-net.it/FUMAPEX/FUMAPEX_ARIANET_home.html.

5.3 End-user guideline for forecasting procedure

A.R.P.A.P. is the end-user of the UAQFIS that will be developed within the FUMAPEX Project for the city of Turin and the whole system is going to be installed at A.R.P.A.P. itself.

At present it is not yet possible for A.R.P.A.P. to foresees exactly the time scheduling of the models output; here is reported the detail of the requested system output.

- The output of the RAMS model (smaller domain) should include surface data of wind, temperature and precipitation and prognostic vertical profiles (wind, temperature and relative humidity) for every three hours from +6 to +48 hours ahead.
- The FARM model should calculate the hourly concentrations of NO_2, PM_{10} and ozone at the monitoring stations located in the target domain from +1 to +48 hours ahead; these data should be used to calculate the AQI. The Internet web-site should report the forecasted AQI and the maps of the simulated pollutants (both the daily averaged concentrations and the maximum of hourly concentrations). Figure 5.7 shows how the information concerning the AQI should appear to the public.



The Air Quality Index for the Turin metropolitan area

The reference scale for the air quality	Air Quality Index value for the last 7 days		Today forecast Saturday 25/10/2003	Tomorrow forecast Sunday 26/10/2003
7 Very Unhealthy	23/10/2003	3	4 Poor	4 Poor
6 Unhealthy	23/10/2003	2	During the day prevailing stability conditions. This situation is favourable to the increase of pollutant concentrations.	During the day prevailing stability conditions. This situation is favourable to the increase of pollutant concentrations.
5 Unhealthy for sensitive groups	22/10/2003	4		
4 Poor	21/10/2003	3		
3 Moderate	20/10/2003	2		
2 Good	19/10/2003	3		
1 Very good	18/10/2003	3		

Figure 5.7: Example of the future daily information concerning the AQI for the Turin metropolitan area.

5.4 References

Carmichael, G.R., Peters, L.K. and Kitada, T. (1986) A second generation model for regional scale transport/chemistry/deposition. *Atmos. Environ., 20*, 173-188.

Carmichael, G.R., Peters, L.K. and Saylor, R.D. (1991) The STEM-II Regional Scale Acid Deposition and Photochemical Oxidant Model-I. An overview of model development and applications. *Atmos. Environ., 25A*, 2077-2090.

Carmichael, G.R., Uno, I., Phadnis, M.J., Zhang, Y. and Sunwoo, Y. (1998) Tropospheric ozone production and transport in the springtime in east Asia. *J. Geophys. Res., 103*, 10649-10671.

Chang, Y.-S., Carmichael, G.R., Ueda, H. and Kurita, H. (1990) Diagnostic evaluation of the components of the STEM-II model. *Atmos. Environ., 24A*, 2715-2731.

Cotton, W.R., Pielke, R.A., Walko, R.L., Liston, G.E., Tremback, C.J., Jiang, H., McAnelly, R.L., Harrington, J.Y., Nicholls, M.E., Carrio, G.G. and McFadden, J.P. (2003) RAMS 2001: current status and future directions. *Meteorol. Atmos. Phys., 82*, 5-29.

Pielke, R.A., Cotton, W.R., Walko, R.L., Tremback, C.J., Lyons, W.A., Grasso, L.D., Nicholls, M.E., Moran, M.D., Wesley, D.A., Lee, T.J. and Copeland, J.H. (1992) A comprehensive meteorological modeling system – RAMS. *Meteorol. Atmos. Phys., 49*, 69-91.

Silibello, C., Calori, G., Finardi, S. and Pirovano, G. (2001) Sensitivity of ozone predictions to prognostic and diagnostic generated meteorological fields. In: *A changing atmosphere - 8th European Symposium on the Physico-Chemical Behaviour of the Atmospheric Pollutants, Torino, 17-20 September 2001.*

Silibello, C. and Calori, G. (2003) FARM (Flexible Air quality Regional Model) model formulation. Report Arianet 2003.

Walko, R.L. and Tremback, C.J. RAMS. Regional Atmospheric Modeling System Version 4.3/4.4 Introduction to RAMS 4.3/4.4. ATMET Report, available on www.atmet.com.

6 Guidelines on the output from the UAQIFS for the city of Bologna, Italy

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Environmental Protection Agency of Emilia – Romagna Region (ARPA)

The basis for the presently applied UAQIFS in Bologna is a forecast procedure and an integrated model system consisting of the ARPA Regional Meteorological Service's meteorological model LAMI (the Italian version of LM, developed by consortium COSMO), two statistical pollution models (OLMO and PIOPPO) and some utilities and procedure for reporting on episodes (GINEPRO). The final AQ forecast and pollution episode report are distributed to the public by Environmental Protection Agency of Emilia-Romagna Region (ARPA) (end-user). The numerical forecasts are issued three days every week, the textual air quality bulletin every day. During winter (October-March) forecasts and bulletin are focused mainly on PM_{10}, on ozone during summer (April-September).

In the sections below are described: the general features of the presently applied UAQIFS and of its components, the forecast and reporting procedures and their output.

6.1 Description of the presently applied Operational UAQIFS for Bologna

6.1.1 The non-hydrostatic meteorological model LAMI

ARPA SMR, as member of the European research consortium COSMO (see also "COSMO Newsletter", http://www.cosmo-model.org/cosmoPublic/), provides daily runs of the non-hydrostatic prognostic model LAMI (the Italian version of LokalModell, operational from June 2003 with LM3.1). In the operational configuration, the model runs on a domain covering Italy and the central Mediterranean (1900 x 1600 km) with rotated spherical grid, horizontal mesh size 0.0625° (~7km, Arakawa C-grid), terrain-following hybrid sigma vertical coordinates, 35 layers covering all of the atmosphere (10 layers in lowest 1500m above model orography).

LAMI uses mean orography derived from GTOPO30 data set (30"x30") of USGS, prevailing soil type from DSM data set (5'x5') of FAO, land-fraction, veg cover, root depth and leaf area index from CORINE data set of ETC/LC (250m), roughness length from GTOPO30 and CORINE. DWD's operational hydrostatic global model GME with icosahedral-hexagonal grid (mesh size ~60km) provides initial and boundary values.

The model is presently operational for 72h forecast (~ 1h CPU on IBM SP4). The operational configuration includes: the prognostic TKE-closure (level 2.5, see Mellor & Yamada, 1974) with refined surface layer scheme including a laminar boundary layer for the subgrid scale turbulence (Raschendorfer, 1999); saturation adjustment for calculation of condensation and evaporation; precipitation formation by parameterised cloud microphysics assuming instantaneous fallout of precipitation particles; δ-two-stream radiation scheme (8 spectral intervals) with full cloud radiation feedback (Ritter & Geleyn, 1992); subgrid cloudiness diagnosed from relative humidity; Tiedtke (1989) mass-flux scheme with equilibrium closure based on moisture convergence; soil processes including snow and interception storage, climate values prescribed as lower boundary conditions.

6.1.2 The meteorological pre-processor CALMET-SMR

At ARPA-SMR a mass-consistent meteorological diagnostic pre-processor is implemented (Deserti *et al.*, 2001). In its operational configuration, the model provides daily runs, with a domain covering the whole Po Valley basin (450 x 260 km), an horizontal resolution of 5 km, 10 vertical terrain-following levels from the surface up to 2500 m. The model processes data measured by the standard meteorological surface stations (temperature, wind, total and low cloud cover, cloud types, relative humidity, precipitation, surface pressure) of the synop network (~20 stations over Northern Italy) and other local networks (~20) and upper air data from 4 radiosounding. Using the Holtslag & Van Ulden scheme, based on the Monin-Obukhov similarity theory and the surface energy budget method, it provides three-dimensional fields of three-dimensional wind and temperature, bidimensional fields of mixing height, Monin-Obukhov length, friction velocity, convective velocity scale and Pasquill-Gifford stability classes.

6.1.3 The statistical pollution models OLMO and PIOPPO

OLMO (Ozone Linear Model) and PIOPPO (PM10 Pollution Polynomial Model) are two statistical linear regressive pollution models.

During summer period, the present version (2002) of OLMO provides ozone daily maxima forecasts for days d+1 and d+2, in 11 urban sites (including a point on the target city Bologna) over a ~240 x 120km area. The model's predictor is the last measured ozone daily maxima in the considered urban sites and the forecasted T_{MAX} over several station-points (Stortini, 2003).

During winter period, the present version (2002) of PIOPPO provides PM_{10} daily average forecasts for days d+0, d+1 and d+2, in 13 urban sites (including a point on the target city Bologna) over a ~240 x 120km area. The model's predictor are the last measured PM_{10} daily average in the considered urban sites and the forecasted T_{MIN}, wind speed and total precipitation over several station-points (Deserti *et al.*, 2002).

The minima and maxima temperature forecasts are Kalman-filtered output of ECMWF (Cacciamani & de Simone, 1992; Costa & Selvini, 2002); the other meteorological forecasted variables come directly from LAMI.

6.1.4 The forecast procedure

The forecast procedure follows these steps:

(1) LAMI is run on IBM SP4 (32 processors) at about 6.30 (local time). The run is finished at about 8.30.

(2) At 7.30, ECMWF temperature forecasts are processed through a Kalman filter to get accurate forecasts of T_{MIN} and T_{MAX} at specific points.

(3) At about 9-10, the ARPA technicians check and validate the pollution data of the previous day, measured by the monitoring network. Data are sent to the regional air pollution database.

(4) On Mondays, Wednesdays and Fridays, at about 10.30, expert technicians of the Meteorological Service of ARPA execute OLMO (during summer) or PIOPPO (during winter). The PM_{10} daily average values calculated by PIOPPO on 13 station points and the ozone daily maxima calculated by OLMO on 11 station points are averaged on three sector, which preliminary studies showed to be often homogeneous for PM_{10} and for ozone pollution. The forecasts are showed with maps with 3 different colours (see Table 6.1). Forecasts are published on the web.

(5) Every morning, expert technicians of the Meteorological Service of ARPA write an AQ-oriented meteorological bulletin. The bulletin is automatically published on the web and sent via e-mail to a list of Local Authorities.

Table 6.1:Ozone and PM_{10} forecasts: terms and colours for their representation.

ozone (µg/m^3)	PM_{10} (µg/m^3)	level (in the textual bulletin)	map sector colour
0 – 120	0 – 50	low	green
120 – 180	50 – 100	medium	orange
> 180	> 100	high	red

6.2 End-user guideline for forecasting procedure

End-users of the forecasts are the population itself and also the Regional Government of Emilia Romagna (in particular the chairman of the Environmental Office), the Provincial Authorities and the Municipalities (in particular those of the 10 most important cities in the Emilia Romagna Region, Bologna included).

Recently (July 14th 2003) they subscribed the 2nd Regional Agreement on Air Quality, focused in particular on PM_{10} pollution management and aiming to reach the target values which the EU stated for 2005. The Agreement establishes traffic reduction actions, promotes car-sharing and car-pooling, informs the population on air pollution and its effects on health, prescribes the definition of local plans for long-term emissions and pollution reduction; it also contemplates the activation of short-term actions for pollution mitigation, when the meteorological conditions are particularly unfavourable.

So the Local Authorities need reliable PM_{10} forecasts., and ARPA is entrusted to provide them. This information is offered to the population through the Internet with a specific site (www.liberiamolaria.it, clicking on “Previsioni PM10”, see also Figure 6.1), where people can also find information on air pollution, its effects on health and traffic reduction actions.

ARPA-SMR provides to the population and to the local authorities analogous forecasts and information about ozone (Figure 6.2, http://www.arpa.emr.it/ozono/).

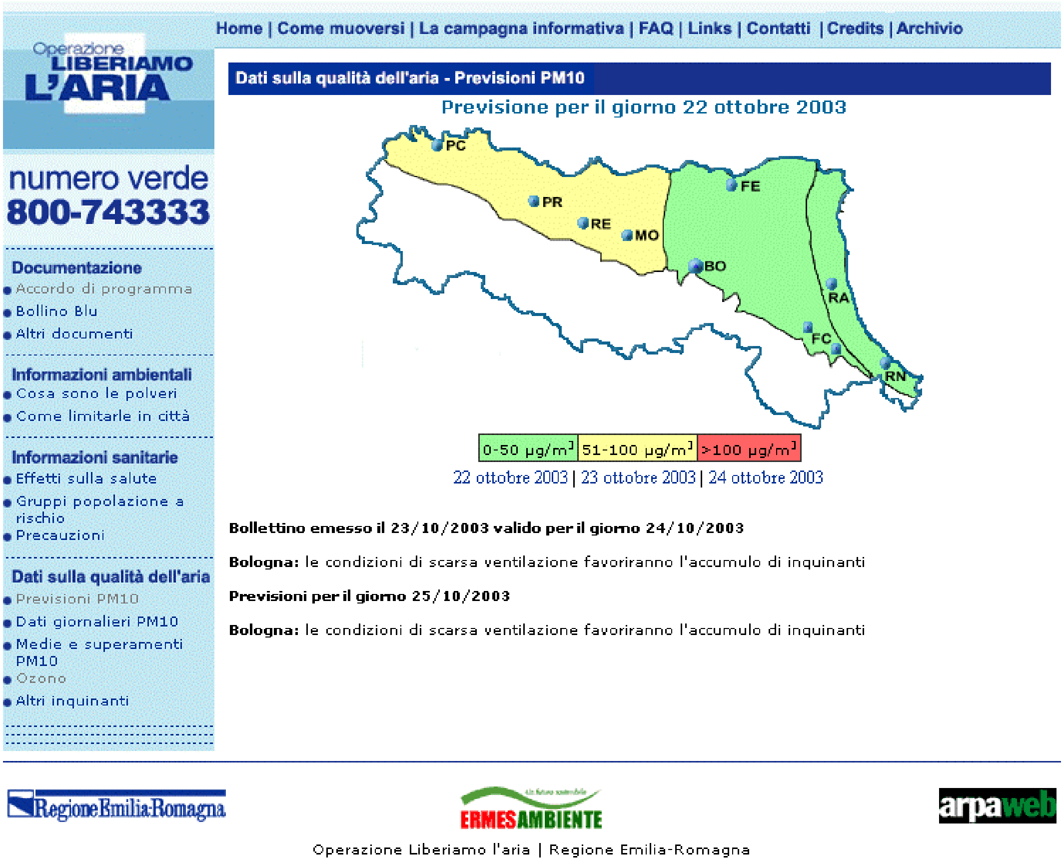

Figure 6.1: The PM_{10} forecasts page on the web, with maps and textual bulletin.

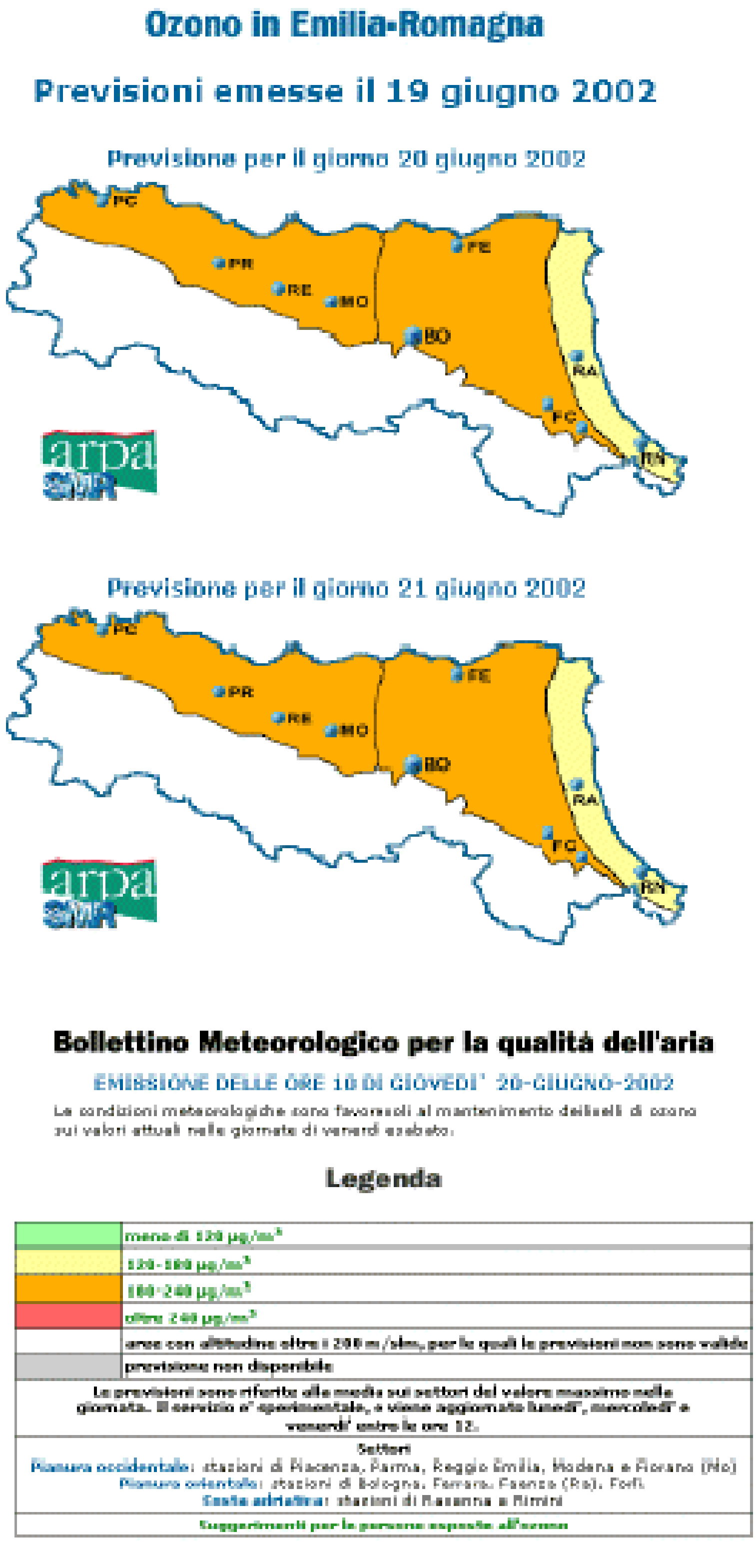

Figure 6.2: The ozone forecasts page on the web, with maps and textual bulletin.

6.3 References

About LM:

Baklanov, A., Rasmussen, A., Fay, B., Berge, E. and Finardi, S. (2002) Potential and shortcomings of numerical weather prediction models in providing meteorological data for urban air pollution forecasting. *Water, Air Soil Poll., Focus, 2,* 43-60.

"COSMO Newsletters", available at: http://www.cosmo-model.org/cosmoPublic/

Doms, G. and Schättler, U. (1999) The nonhydrostatic limited-area model LM, part1: scientific documentation. Offenbach, Deutscher Wetterdienst.

Jacobsen, I. and Heise, E. (1982) A new economic method for the computation of the surface temperature in numerical models. *Beiträge Phys. Atm., 55*,128-141.

Louis, J.-F. (1979) A parametric model for vertical eddy fluxes in the atmosphere. *Bound. Lay. Met., 17,* 187-202.

Mellor, G.L. and Yamada, T. (1974) A hierarchy of turbulence closure models for planetary boundary layers. *J. Atmos. Sci., 31,* 1791-1806.

Raschendorfer, M. (1999) The new turbulence parameterization of LM. *Quarterly Report of the Operational NWP-Models of the DWD, No 19, 3-12, May 1999*.

Ritter, B. and Geleyn, J.-F. (1992) A comprehensive radiation scheme for numerical weather prediction models with potential applications in climate simulations. *Mon. Wea. Rev., 96,* 351-356.

Tiedtke, M. (1989). A comprehensive mass flux scheme for cumulus parameterization in large-scale models. *Mon. Wea. Rev., 117*, 1779-1800.

About Kalman filter:

Cacciamani, C. and de Simone, C. (1992) Un automa stocastico per le previsioni locali. *Riv. Meteor. Aeronautica*, *52*, n. 1-2 (in Italian).

Costa, S. and Selvini A. (2002) Manuale programmatore del filtro di Kalman. (Internal Report ARPA-SMR No. 08/2002) (in Italian). Available at: http://www.arpa.emr.it/smr/archivio/downloads/quaderni/Quaderno_Tecnico_08_2002.pdf

About CALMET-SMR:

Deserti, M., Cacciamani, C., Golinelli, M., Kerschbaumer, A., Leoncini, G., Savoia, E., Selvini, A., Paccagnella, T. and Tibaldi, S. (2001) Operational meteorological pre-processing at Emilia-Romagna ARPA Meteorological Service as a part of a decision support system for Air Quality Management. In: *Proceedings of the Sixth Workshop on Harmonisation within Atmospheric Dispersion Modelling for Regulatory Purposes*. Ed. by Prof. A. Coppalle. *Int. J. Environ. Poll., 16*, Nos. 1-6.

Scire, J.S., Insley, E.M. and Yamartino, R.J. (1990) Model formulation and user's guide for the CALMET meteorological model. Rep. No. A025-1, Sigma Research Corporation, prepared for the California Air Resources Board, Sacramento, CA.

About PIOPPO and OLMO:

Stortini, M. (2003) OLMO e Arpaweb per le previsioni dell'ozono (in Italian). (ARPA Rivista No. 3/2003). Available at: http://www.arpa.emr.it/smr/archivio/downloads/ambiente/ozononuovo.pdf

Deserti, M., Stortini, M., Bonafe', G., Minguzzi, E., Frontero, P., De' Munari, E. and Mazza, D. (2002) Inquinamento da polveri in Emilia-Romagna. Analisi a fini previsionali e comparazione con la situazione meteorologica a larga scala. (Internal Report ARPA-SMR No. 10/2002) (in Italian). Available at: http://www.arpa.emr.it/smr/archivio/downloads/quaderni/Quaderno_Tecnico_10_2002.pdf

Websites:

COSMO Newsletters: http://www.cosmo-model.org/cosmoPublic/

CALMET-SMR (in Italian): http://www.arpa.emr.it/smr/pagine/sapernedipiu/download/?topic=ambiente

Ozone forecasts and information (in Italian): http://www.arpa.emr.it/ozono/

PM_{10} forecasts and information (in Italian): http://www.liberiamolaria.it/previsioni.asp

Emilia Romagna severe pollution episodes reports (in Italian): http://www.arpa.emr.it/smr/pagine/ambiente/eventi/

2nd Regional Agreement on Air Quality (in Italian): http://www.liberiamolaria.it/accordo.asp

7 Guidelines on the output from the emergency preparedness system for the city of Copenhagen, Denmark

Authors: Steen Hoe [(1)], Alexander Baklanov [(2)] and Jens Havskov Sørensen [(2)]

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[(2)] Danish Meteorological Institute (DMI)

For the Copenhagen Metropolitan Area and the Øresund region (including the cities of Copenhagen and Malmø), where the system will be tested for the emergency aspects (hypothetical accident or terror action), the focus will be on radioactive materials first of all.

The Danish Emergency Management Agency (DEMA, in Danish: Beredskabs-styrelsen), which is an institution under the Ministry of the Interior, is responsible for the Danish nuclear emergency preparedness. A number of national institutions and authorities contribute to the Danish nuclear preparedness, and DMI is among them. The preparedness comes into force in case of a nuclear accident posing a risk to the Danish population. The aim of the preparedness is to implement the best measures to protect people against radioactivity, and to inform the general public. Hereby, injuries to the health can be avoided or reduced.

DMI is responsible for making forecasts of the transport, diffusion and deposition of a radioactive plume. DMI delivers also real time high-resolution forecast meteorological data from the DMI-HIRLAM model system to DEMA for an area covering Denmark and its surroundings. These data will be used in case of accidents at nuclear installations in Denmark or surroundings by the Accident Reporting and Guidance Operational System (ARGOS) (Hoe *et al.,* 1999, 2002). By using the Local Scale Model Chain (LSMC), developed at the Risø National Laboratory, ARGOS can calculate forecasts of radioactive doses and concentrations.

DEMA (Subcontractor 1.3) acts in FUMAPEX as an end-user of the results and methods to be developed in the project for emergency preparedness purposes.

The main item for this work in FUMAPEX is to improve urban high-resolution NWP model forecasting data for the Copenhagen Metropolitan Area and to make it available to the ARGOS emergency preparedness decision-support system. In ARGOS the data will be used for simulation of hypothetical atmospheric releases of toxic or radioactive matters (arising from e.g. an accident or a terrorist action). The scenarios will include hypothetical releases of radioactivity, e.g., from the Barsebäck nuclear power plant, which is located only 20 kilometres from the Copenhagen city centre. Assessments will be made of the implications for the emergency management and of the consequences for the citizens of Copenhagen and suburbs.

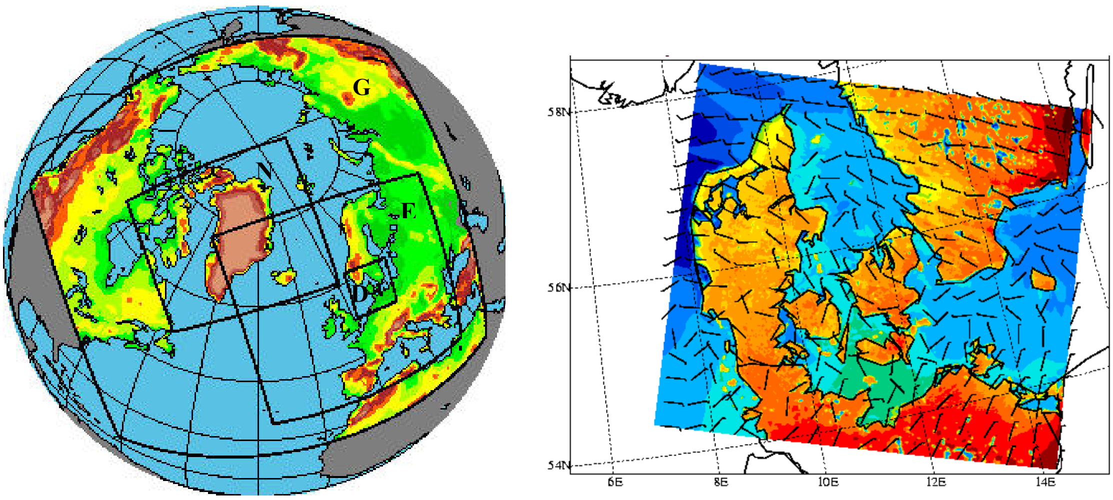
In the section below a general description of the presently applied ARGOS system and NWP forecasting is given. In section 2 the end-users, in collaboration with the modellers, have constructed a guideline for the forecast procedure, thereby defining the desired output from the forecasting system.

7.1 Description of the presently applied Operational Emergency Modelling for Danish cities

7.1.1 Meteorological models and forecast at DMI

The main objective of the operational NWP system at DMI is to provide meteorological forecasts for Denmark, Northern-Europe and the Arctic, including Greenland and the Faeroe Islands.

The Danish operational NWP system consists of several nested models named DMI-HIRLAM 'G', 'N', 'E' and 'D', where the high resolution model 'D', covering an area around Denmark, has approximately 5 km horizontal grid and uses boundary values from the large scale model 'E' (Figure 7.1a). The growth of computer power (new NEC-SX6 supercomputer) and the implementation of grid nesting techniques allow the DMI NWP system to approach the resolution of the city-scale (Sattler, 1999; Sass, 2002; Baklanov *et al.,* 2002). The latest two years, DMI has in limited periods run semi-operationally an experimental version of DMI-HIRLAM over Denmark, including the Copenhagen metropolitan area, with the horizontal resolution of 1.5 km (Figure 7.1b). The vertical structure of the operational DMI-HIRLAM is given by 40 vertical levels. Examples of forecasted wind fields at 10 meter height and of 2 meter air temperature for the Zealand island and the Copenhagen metropolitan area are presented in Figure 7.5.



a **b**

Figure 7.1: DMI-HIRLAM NWP system domains: a) four nested operational versions (G, N, E, D), b) experimental city-scale (1.5 km resolution) version (I) for the Danish territory.

The DMI-HIRLAM model uses a land-use classification with 1 km resolution from GLCC and KMS data. The database describes 21 types of land cover including a separate class of urban areas (Sattler, 1999), see Table 7.1.

Table 7.1:Land-use categories in DMI-HIRLAM.

Value	Description
1	Crops, Mixed Farming
2	Short Grass
3	Evergreen Needle-leaf Trees
4	Deciduous Needle-leaf Tree
5	Deciduous Broad-leaf Trees
6	Evergreen Broad-leaf Trees
7	Tall Grass
8	Desert
9	Tundra
10	Irrigated Crops
11	Semi-desert
12	Ice Caps and Glaciers
13	Bogs and Marshes
14	Inland Water
15	Ocean
16	Evergreen Shrubs
17	Deciduous Shrubs
18	Mixed Forest
19	Interrupted Forest
20	Water and Land Mixtures
21	Urban area

7.1.2 Meteo-data for the ARGOS system

The ARGOS system utilises data from a national numerical meteorological service like the Danish Meteorological Institute (DMI) for the prediction of doses and consequences on local and European scales. In Denmark such data are provided by the Danish Meteorological Institute. The data are transferred online to the Danish Emergency Management Agency and into the ARGOS system.

The DMI-HIRLAM-E forecast model covers presently all of EU and a large part of the former Soviet Union with 16 km horizontal resolution and a 40 vertical levels. Running in a 3 hour updated data-assimilation cycle, this model forecast, e.g., wind, temperature, humidity, heat fluxes and precipitation up to 54 hours ahead.

In ARGOS currently data for 16 vertical levels are used as well as single-level parameters. The data provided includes wind speed and direction, virtual potential temperature, specific humidity, geopotential height, boundary layer height, roughness, fraction of land, and precipitation. From these data an atmospheric stability field is derived using the so-called local scale pre-processor (LSP).

In the bounds of the FUMAPEX project the ARGOS system will be tested with higher resolution and more advanced NWP data for the Copenhagen area.

7.1.3 The meteorological pre-processor

A meteorological pre-processing interface is translating and interpolating the NWP model output so as to meet the input requirements of the ARGOS system.

The atmospheric dispersion system used in ARGOS, the Local Scale Model Chain (LSMC), is a comprehensive meteorological dispersion module for emergency response.

LSMC comprises a meteorological pre-processor (pad), which calculates deposition- and stability parameters and wind fields based on the data provided by the DMI-HIRLAM model. The DMI-HIRLAM data set used cover the height interval from 0 to approximately 3000 meters above ground.

These data are pre-processed and interpolated by the pad to yield data input fields for the RIMPUFF local-scale atmospheric model. Typically the fields are interpolated to a grid spacing of about 1 to 2 km. The wind fields are interpolated either by the linearized flow model Lincom or by $1/r^2$ weighting. In order to provide a more detailed wind field near the source, Lincom is only used out to about 50 km from the source when the variability of the wind direction is low. Lincom can be turned off. The 16-layer wind fields are also used by RIMPUFF to calculate wind shear.

7.1.4 ARGOS system

Prognosis modules

The atmospheric dispersion system of ARGOS, Local Scale Model Chain (LSMC) is used for production of estimates of actual and forecasted (+48 hour) ground-level air concentrations, wet and dry deposition, and ground-level gamma dose rates on short and medium range scales (~100 km). It includes the atmospheric local-scale dispersion model RIMPUFF (RIsø Mesoscale PUFFmodel), developed at the Risø National Laboratory (Mikkelsen *et al.,* 1997), as a prognostic tool.

Source terms for specific reactors and release categories are defined in the ARGOS database. The source term for each reactor is split into a number of user defined time steps, and for each time step the activity for each radionuclide is individually defined. Presently the nuclide database contains the 361 radio-nuclides. When the reactor and the release are specified, a calculation of a 54 hours forecast takes typically around 15 minutes.

The result of the prognosis includes nuclide specific air concentrations, ground contamination, γ dose from cloud, inhalation doses, and external doses.

The RIMPUFF Local-scale Dispersion Model

The dispersion of radioactive material in the atmosphere is calculated by RIMPUFF. RIMPUFF is a fast and operational puff diffusion code that is suitable for real-time simulation of puff and plume dispersion using time- and space-changing meteorology. The model calculates dry and wet deposition of the material released. Gamma doses from airborne and deposited radioactivity may also be calculated.

Data from RIMPUFF are processed in ARGOS to yield inhalation doses for children and adults as well as external doses from deposition. Further the model is provided with a puff splitting feature to deal with plume bifurcation and flow divergence due to channelling, and slope flow and inversion effects in non-uniform terrain.

In RIMPUFF the puff diffusion processes are controlled by local turbulence levels, either provided directly from onsite measurements, or via pre-processor calculations. RIMPUFF is further equipped with standard plume rise formulas, inversion and ground level reflections, as well as gamma dose algorithms and wet/dry depletion.

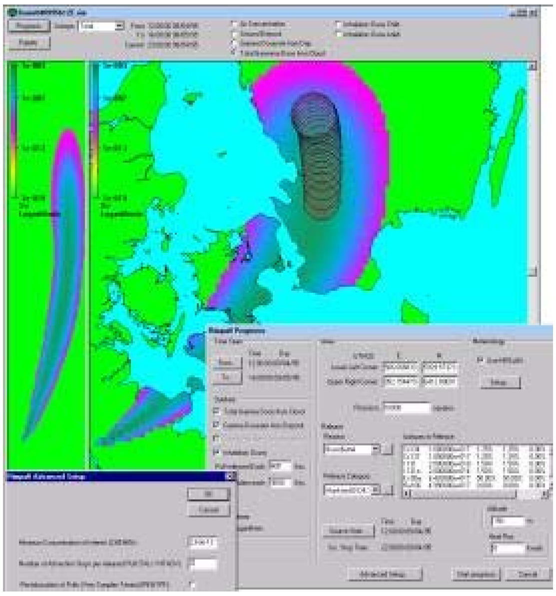


Figure 7.2: RIMPUFF prognosis for simulated release from a NPP.

For real-time applications, RIMPUFF can be based on wind data from sources like:

- A permanent network of meteorological towers,
- A flow model for moderately complex terrain (e.g. LINCOM), and
- Online numerical meteorological forecast data.

Dispersion calculations

RIMPUFF calculates the puffs' locations on the specified grid by computing their movement during finite time steps. The actual (time averaged) wind vector (wind direction and wind speed) at the puff centre is used to advect the individual puffs. To compute the growth and buoyant lift of the puffs, the turbulence parameter fields provided by the pad are used.

The stability parameters provided for RIMPUFF pertain to similarity parameterisations, which gives a continuous atmospheric stability spectrum. The similarity parameters are the most realistic stability parameterisation under most atmospheric conditions. However, when considering large travel times/distances and/or inhomogeneous wind- and turbulence fields, several other items must be considered:

Splitting of puffs: A more realistic handling of vertical and horizontal wind shear is obtained by splitting the puffs when certain criterias are met. The splitting methods are called trifurcation in the vertical (3 new puffs), and pentafurcation (5 new puffs) in the horizontal. In all cases, mass and momentum is conserved. The splitting method is optimised in order to avoid unnecessary puff splitting.

Vertical growth of puffs: In RIMPUFF it is assumed that puff centre height increases with increasing vertical dispersion. This will eventually lead to puffs reaching above the boundary layer.

A special turbulence parameterisation for puffs above the Atmospheric Boundary Layer (ABL) is used. As the ABL height changes with time, the puffs are allowed to move in and out of the ABL.

Plume rise: RIMPUFF uses Brigg's formula. It is currently being considered, especially large energy releases, to employ a set of recently developed plume rise formulas (Sorokovikova, 1999). These formulas can handle explosive heat releases, which may lead to a plume rising above the ABL. Humidity and temperature profiles from HIRLAM will be used in this relation.

Dry deposition is calculated using the source depletion method. The nuclide specific dry deposition parameters are calculated using the so-called surface resistance method. This means that the parameters mainly depend on turbulence and land use. Typically, it is so that compared to an open grass field there is large deposition over forest areas and low deposition over cities. Land use data may be obtained from satellite pictures.

Gamma dose and concentration calculations are also made by RIMPUFF. Decay of radionuclides as well as production of daughter elements during air transport and after deposition on the ground is taken into account. The gamma doses from the puffs are calculated using the finite cloud model and assuming that the puffs are spherical. For deposited material, the gamma doses are calculated assuming a semi-infinite plane source. Based on the output from RIMPUFF, ARGOS calculates external doses separately for adults and children: Effective doses , inhalation doses, thyroid doses and also the avoidable doses from sheltering are calculated.

RIMPUFF may be used out to about around 100 kilometres from the source. With some careful tuning RIMPUFF may calculate trajectory-like results on even longer distances. At distances from about 20 kilometres from the source the DMI long-range atmospheric dispersion model, the Danish Emergency Response Model of the Atmosphere (DERMA), is used. Thus the RIMPUFF and DERMA models have a common range covered.

The DERMA Regional-scale Dispersion Model

The Danish Emergency Response Model of the Atmosphere (DERMA) is used for the real-time modelling of possible contamination and consequences (cf. Figure 7.3). The model is developed at the Danish Meteorological Institute (DMI) mainly for nuclear emergency preparedness purposes. DERMA is a 3-D Lagrangian long-range dispersion model using a puff diffusion parameterisation, particle-size dependent deposition parameterisations and radioactive decay (Sørensen, 1998; Sørensen *et al.,* 1998; Baklanov and Sørensen, 2001). Earlier comparisons of simulations by the DERMA model vs. the ETEX experiment involving passive tracers gave very good results. 28 institutions from most European countries, USA, Canada and Japan contributed to the real-time model evaluation. Based on analyses from the first experiment, the DERMA model was emphasised as being very successful (Graziani *et al.,* 1998). In general, the DERMA model can be used with different sources of NWP data, including the DMI-HIRLAM and ECMWF NWP models with different resolution.

The main objective of the DERMA model is to predict the atmospheric transport, diffusion, deposition and radioactive decay of a radioactive plume within a range from about 20 kilometres from the source up to the global scale.

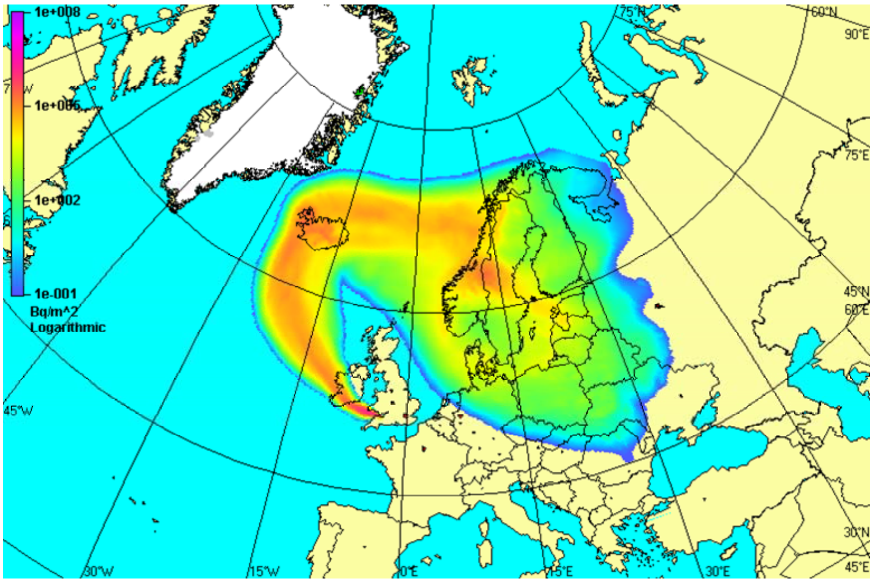


Figure 7.3: A regional-scale DERMA plume (total deposition) as visualised by ARGOS.

DERMA is run on operational computers at DMI. The integration of DERMA in ARGOS is effectuated through automated on-line digital communication and exchange of data. The calculations are carried out in parallel for each NWP model to which DMI has access, thereby providing a mini-ensemble of dispersion forecasts for the emergency management.

The FUMAPEX project aims at improving meteorological forecasts for urban areas, and thereby urban air pollution models. The latter include dispersion models, which will be used in case of accidental releases of hazardous material or terror actions.

In recent years, DMI has run an experimental version of DMI-HIRLAM over Denmark including the Copenhagen metropolitan area with a horizontal resolution of 1.4 km, thus approaching the city scale. This involves 1-km resolution physiographic data with implications for the surface parameters, e.g. surface fluxes, roughness length and albedo. The enhanced high-resolution NWP forecasting will be provided to demonstrate the improved dispersion forecasting capabilities of ARGOS for the city of Copenhagen.

Dose calculations

The dose calculations can be carried out by different methods using different sources of data:

- From multiple γ dose rate measurements in a selected time span, a simple integration can be performed.
- From air concentration measurements of specific radionuclides measured during the plume passage, the total outdoor Committed Effective Dose from inhalation can be calculated for both adults and children.
- The total external γ dose received during the plume passage can be estimated by adding the γ dose from the plume and the γ dose from the deposited activity on the ground.
- The Food Dose Module (ARGOS FDMT 2.0) can be applied.

7.2 Forecast procedure and end-user guidelines

Early warning and emergency preparedness issues

The availability of reliable UAQIFS with urban scale weather and pollution forecasts could be of relevant support for emergency management regarding (i) fires, (ii) accidental radioactive, toxic or infectious emissions, (iii) potential terrorist attacks with radioactive, chemical or biological matter releases, etc.

The overall ARGOS emergency preparedness system consists of various parts, LSMC, dose models, DMI-HIRLAM and DERMA, as depicted in Figure 7.4.

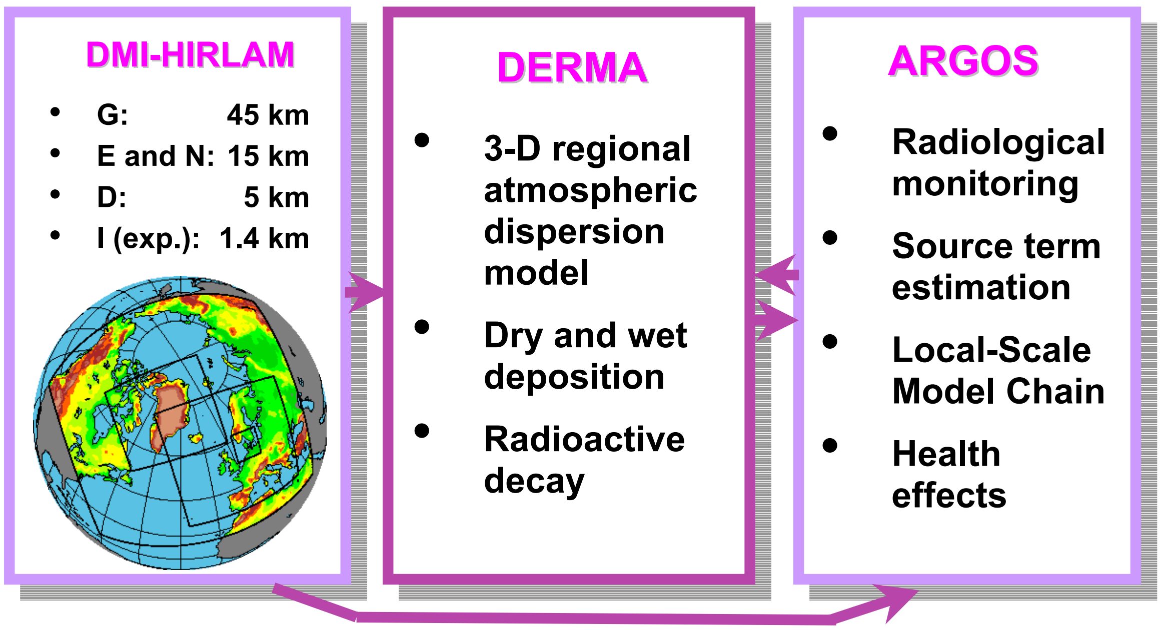


Figure 7.4: The DMI-HIRLAM numerical weather prediction model versions, the DERMA regional atmospheric dispersion model, the ARGOS real-time on-line nuclear decision support system, and links between.

DEMA (end-user in the FUMAPEX project) has defined a detailed guideline for the emergency preparedness / forecasting procedure in close collaboration with different Danish organisations involved. These guidelines provide a detailed description of the outputs and main functions of the ARGOS system as requested by the end-users.

ARGOS Functions:

- Warning
    - PMS
    - Data Exchange
- Pre Release / Release
    - Atmospheric dispersion (LSMC – DERMA)
    - Food Dose Module (ARGOS FDMT 2.0)
    - Monitoring
- Deposition
    - Monitoring
    - Atmospheric dispersion (LSMC)
    - Food Dose Module (ARGOS FDMT 2.0)

Release Characteristics

- Emergency preparedness
- Point sources
- Nuclear: meso- to regional scale
- Biological/Chemical: small- to meso-scale

<u>Pre-release Phase</u>

- Prognosis (LSMC)
- Data
  - Gamma stations
  - Radar (rain)

<u>Plume Phase:</u>

- Monitoring
  - Gamma stations
  - Radar (rain)
  - Emergency corps (external γ)
  - Air samples
  - Helicopter (external γ)
- Atmospheric prognosis (LSMC, DERMA)
  - Long Term modelling (FDMT)

<u>After Deposition:</u>

- Monitoring
  - Helicopter (γ spectra / deposition)
  - Food samples
- Long Term modelling (FDMT).

In the bounds of the FUMAPEX items, DMI has run an experimental version of DMI-HIRLAM over Denmark including the Copenhagen metropolitan area with a horizontal resolution of 1.4 km. This involves 1-km resolution physiographic data with implications for the surface parameters, e.g. surface fluxes, roughness length and albedo. The enhanced high-resolution NWP forecasting will be provided to demonstrate the improved dispersion forecasting capabilities of ARGOS for the city of Copenhagen. In Figure 7.5 an example is given of results from this model version, and in Figure 7.6 a corresponding RIMPUFF local-scale plume is shown.

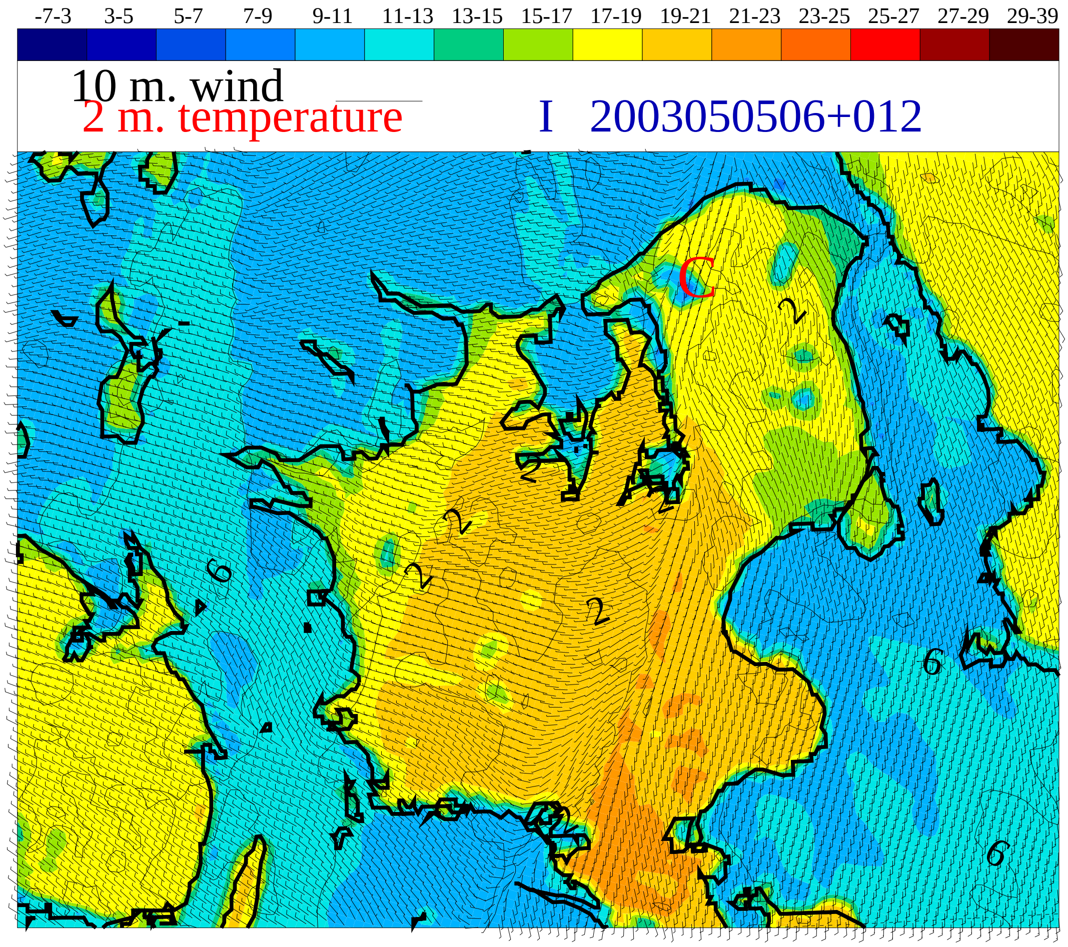


Figure 7.5: A semi-operational version of DMI-HIRLAM with 1.4-km resolution and covering Denmark is run on a test basis. The figure shows an example of 12-hour forecasts of wind at 10 m height above ground and temperature at 2 m height for the Copenhagen Metropolitan Area and surroundings (the Sjælland Island).

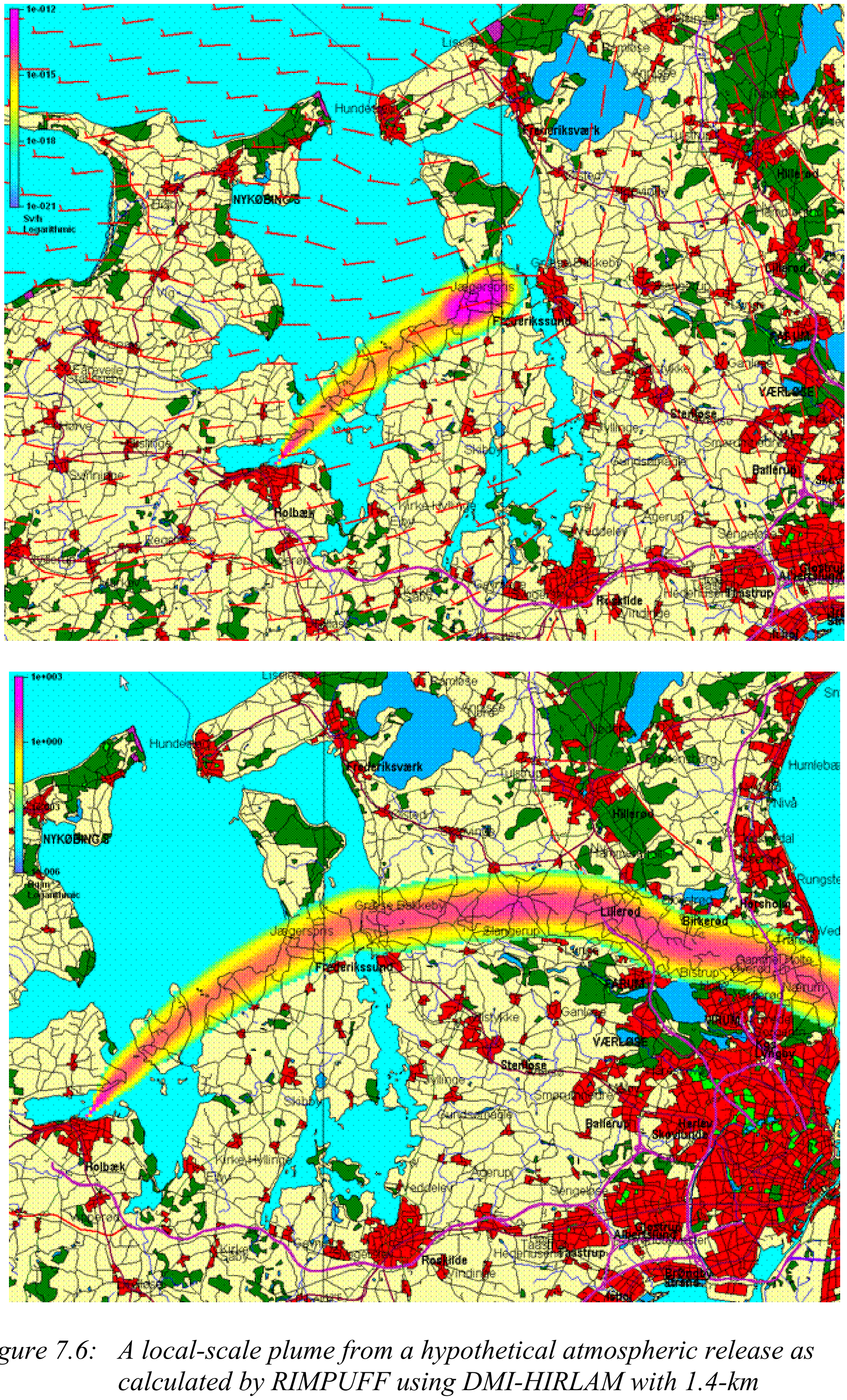


Figure 7.6: A local-scale plume from a hypothetical atmospheric release as calculated by RIMPUFF using DMI-HIRLAM with 1.4-km resolution and visualised by ARGOS for the Copenhagen Metropolitan Area.

7.3 References

About ARGOS: http://www.nucinfo.com/Information/argos/argos-technical.htm

Baklanov, A. and Sørensen, J.H. (2001) Parameterisation of radionuclide deposition in atmospheric dispersion models. *Phys. Chem. Earth, 26,* 787–799.

Baklanov, A., Rasmussen, A., Fay, B., Berge, E. and Finardi, S. (2002) Potential and shortcomings of numerical weather prediction models in providing meteorological data for urban air pollution forecasting. *Water, Air Soil Poll. Focus, 2,* 43-60.

Baklanov, A., Sørensen, J.H. and Hoe, S. (2003) FUMAPEX EU project: urban meteorological modelling for nuclear emergency preparedness. NKS Conference on Radioactive Contamination in Urban Areas, May 7-9, 2003, Risø, Roskilde, Denmark.

Ehrhardt, J., Brown, J., French, S., Kelly, G.N., Mikkelsen, T. and Müller, H. (1997) RODOS: Decision-making support for off-site emergency management after nuclear accidents. *Kerntechnik, 62*, 122-128.

Hoe, S., Sørensen, J.H. and Thykier-Nielsen, S. (1999) The nuclear decision support system ARGOS NT and early warning systems in some countries around the Baltic Sea. In: *Proceedings of the 7th Topical Meeting on Emergency Preparedness and Response, September 14–17, 1999, Santa Fe, New Mexico, USA*.

Hoe, S., Müller, H., Gering, F., Thykier-Nielsen, S. and Sørensen, J.H. (2002) ARGOS 2001, a decision support system for nuclear emergencies. In: *Proceedings of the Radiation Protection and Shielding Division Topical Meeting, April 14–17, 2002, Santa Fe, New Mexico, USA.*

Mikkelsen, T., Thykier-Nielsen, S., Astrup, P., Santabárbara, J.M., Sørensen, J.H., Rasmussen, A., Robertson, L., Ullerstig, A., Deme, S., Martens, R., Bartzis, J.G. and Päsler-Sauer, J. (1997) MET-RODOS: A comprehensive atmospheric dispersion module. *Radiat. Prot. Dosim., 73*, 45–56.

Sass, B.H., Nielsen, N.W., Jørgensen, J. U., Amstrup, B., Kmit, M. and Mogensen, K.S. (2002) The operational DMI-HIRLAM system – 2002 version (DMI Tech. Rep., 02-05 (2002)). URL: www.dmi.dk/f+u/publikation/tekrap/2002/Tr02-05.pdf

Sørensen, J.H. (1998) Sensitivity of the DERMA long-range dispersion model to meteorological input and diffusion parameters. *Atmos. Environ., 32*, 4195–4206.

Sørensen, J.H., Baklanov, A. and Hoe, S. (2003) Regional atmospheric dispersion modelling and urban meteorological effects integrated in ARGOS. 'Off-site Nuclear Emergency Management' International Symposium. 29 September – 3 October 2003, Salzburg, Austria.

Sørensen, J.H., Rasmussen, A., Ellermann, T. and Lyck, E. (1998) Mesoscale influence on long-range transport; evidence from ETEX modelling and observations. *Atmos. Environ., 32*, 4207–4217.

8 Concluding remarks

This report presents the technical specifications of the UAQIFS' to be applied in the six target cities selected for implementation and demonstration in WP8 of the FUMAPEX project.

As seen in the preceding sections, differences in orographic-, climatic-, and pollution characteristics within the various target city areas clearly lead to differences in methodical approach. An example is the use of hydrostatic NWP models (variants of the HIRLAM model) in the target cities surrounded by practically flat terrain like Copenhagen, Helsinki, and Valencia/Castellon, whereas non-hydrostatic mesoscale circulation models (RAMS, MM5, LAMI) are applied in more complex terrain areas like Turin, Oslo, and Bologna. There is also a clear north-south difference in that the UAQIFS is focused on predicting (mostly wintertime) episodes of NO_2 and PM_{10} in the northern cities (Helsinki and Oslo) while summertime ozone forecasts is of equal importance for the southern cities (Valencia/Castellon, Turin and Bologna). Since the UAQIFS for the Copenhagen Metropolitan area is an emergency preparedness system, this system primarily focuses on accidental releases of radioactive materials.

The end-users of the project have been heavily involved in the writing of this report. Their main contribution have been in:

- specifying the guidelines for the practical forecasting procedure to be applied in the system,
- defining content and format of needed forecasts and warnings,
- defining the data dissemination to decision-makers, central and local authorities, and to the public in general.

This end-user involvement is also essential in order to promote further application of the scientific achievements within FUMAPEX beyond the three-year project period. The implementation of similar systems in other cities will benefit considerably from the experience gathered through the implementation, testing and demonstration exercise performed in FUMAPEX. Cities like Budapest, Prague, Paris and Vilnius have already shown interest in this type of air quality forecasting systems.

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REPORT SERIES SCIENTIFIC REPORT	REPORT NO. OR 2/2004	ISBN 82-425-1532-8 ISSN 0807-7207	
DATE	SIGN.	NO. OF PAGES 81	PRICE NOK 150.-
TITLE FUMAPEX Guidelines of output from UAQIFSs as specified by end-users		PROJECT LEADER Leiv Håvard Slørdal NILU PROJECT NO. U-102144	
AUTHOR(S) Edited by Leiv Håvard Slørdal		CLASSIFICATION * A CONTRACT REF. EVK4-CT-2002-00097	
REPORT PREPARED FOR European Commission			

ABSTRACT

The major goal of the FUMAPEX project is to improve the performance of Urban Air Quality Information and Forecasting Systems (UAQIFS) presently applied in various urban areas in Europe. The scientific focus is on improving the meteorological forecast data that are applied as input to the UAQIFS. The scientific improvements are then to be demonstrated in six European target cities. The demonstration activity has been defined as a separate Work Package (WP8) within the project. The present report (deliverable 8.1) gives a detailed technical specification of each of the UAQIFS, which are to be demonstrated in Oslo (Norway), Helsinki (Finland), the Castellon area (Spain), Turin (Italy), Bologna (Italy), and Copenhagen (Denmark).

NORWEGIAN TITLE

FUMAPEX. Kravspesifikasjon av utgangsdata fra varslingssystemer for luftkvalitet, spesifisert av sluttbrukere

KEYWORDS		
Urban	Air quality	Forecasting systems

ABSTRACT (in Norwegian)

Hovedmålet i prosjektet FUMAPEX er å forbedre systemene som i dag benyttes for luftkvalitetsvarsling i ulike Europeiske byer. Det forskningsmessige fokus er rettet mot forbedringer i de meteorologiske prognosedataene som brukes som inngangsdata til luftkvalitetsvarselet. De forskningsmessige resultatene skal deretter demonstreres i seks utvalgte europeiske byer. Demonstrasjonsaktiviteten er blitt definert som en egen arbeidspakke (arbeidspakke 8) innenfor prosjektet. Den foreliggende rapport (leveranse 8.1) gir en detaljert teknisk spesifikasjon av varslings-systemene som skal demonstreres i Oslo (Norge), Helsinki (Finland), Castellon (Spania), Torino (Italia), Bologna (Italia) og København (Danmark).

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	C	*Classified (not to be distributed)*