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Providing multi-modal access to environmental data—customizable information services for disseminating urban air quality information in APNEE

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Abstract

APNEE (Air Pollution Network for Early warning and online information Exchange in Europe) is establishing a uniform information portal on air quality in different European regions. Rather than elaborating sophisticated air quality management and forecasting approaches, APNEE is striving to develop a technical umbrella for the distribution and customization of existing air quality management systems. It employs several communication channels—including short message services, mobile communication protocols, and street panels—to transmit information on air quality to selected citizens in urban regions in a customized fashion, tailoring the information content (i.e. the kind of warnings or recommendations for further actions) to the user group registered, to the technical capabilities of the end-user devices targeted, and of course to the geographic location. APNEE will study the feasibility of different broadcasting methods and evaluate them with regard to acceptability, potential impact on citizen behaviour, future markets for online environmental information services for city authorities, telecommunication service providers and other entrepreneurs in

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the information society. Overall, APNEE will provide an enabling technology to implement European directives and national legislation for online dissemination of air quality information.

Keywords: WebGIS; SMS; WAP; Air pollution; Forecast models; OPANA; AIRQUIS; CART; European Commission; 5th Framework Programme; APNEE; Air pollution portal

1. Introduction

The need to provide access to information relating to the state and the management of the urban atmospheric environment has increased rapidly in recent decades in Europe and in the United States (Elsom, 1996). Urban air quality management and information systems (UAQMIS) are now more frequently required to include advanced capabilities for providing quick, effective and easy-to-understand environmental information. These systems are based on the needs of city authorities and national governments to establish frameworks that enable them to take action to ensure that air quality is improved and relevant standards are maintained in urban areas. Such systems try to address the complex interactions between the various physical, ecological, socio-economic and political aspects, components and actors relating to urban air quality, thus posing a considerable challenge to planners, policy- and decision-makers and the general public. As a consequence, such systems should be able to provide the public with clear and easy-to-understand information on the state of the urban atmospheric environment and the management of actions resulting from policies and measures adopted by urban environmental authorities and decision-makers (Karatzas & Moussiopoulos, 2000b).

APNEE (Air Pollution Network for Early warning and online information Exchange in Europe) began as an EU-funded project in January 2000 to establish a uniform information portal on air quality in different European regions. It will implement EU directives on information services for citizens about health-threatening air pollution conditions. The early warning services will be based on comparison between a combination of measurements and/or modelling results with air quality guidelines. If the measurements or model results exceed the air quality (AQ) standards for a region/country, the system will automatically give an alarm. This will be generated automatically in the air quality management system and, after approval by a local expert, will be transferred to the private units via different information channels.

Conceptually speaking, APNEE will develop a harmonized classification schema for a uniform categorization of environmental data and will further develop forecasting methods. Experience gained in other EU-funded projects where broad environmental classification schemes have been developed will be valuable for creating this harmonized environmental schema in APNEE. Moreover, a generalized approach to establishing the requirements of cities and urban regions for the dissemination of environmental information is being elaborated and applied in the very process of defining the requirements.

From a technical viewpoint, an environmental information portal will be developed to provide harmonized information services to citizens. Existing air quality management systems in the cities and regions of Athens, Madrid, Marseilles and Grenland (near Oslo, Norway)—the validation sites in APNEE—will be hooked up to deliver online data on air quality. Impacts on air quality will also be anticipated by dedicated forecasting methods in order to allow citizens and decision-makers to adjust their behaviour and to perform appropriate actions. Such a combination of air quality forecasting tools with scenario analysis and quasi-real-time communication with the citizen (mobile telephone technologies, etc.) will be the future of air quality management tools.

2. Access to environmental information

Access to environmental information has emerged as a crucial service to citizens, driven by various EU directives and national legislation, have stimulated the development of a variety of means for disseminating environmental information.

2.1. Legislative background and practice in Europe

National legislation in European countries on air quality information is based on the general right of public access to information. This right is established in the constitutions of Austria, Germany, Greece, Denmark, the Netherlands, Norway, Portugal and Spain. In addition to legislation on access to information in general, regulations on access to environmental information have been approved in various EU countries. All the above countries (except Portugal and Norway), and additionally Ireland, Switzerland and the UK, have adopted law(s) regulating access to environmental information. These regulations are the result of the implementation of directive 90/313/EEC on the Freedom of Access to Information on the Environment of their National Legislation Body/System. Public information provision is also foreseen in article 5 of directive 92/72/EEC (on air pollution by ozone). In addition, another recently adopted directive [99/30/EC, AIR-EIA Consortium (2001)], on limits to sulphur dioxide, nitrogen dioxide and oxides of nitrogen, particulate matter and lead in ambient air, emphasizes (in article 1) the need for public air quality information, while article 8 is completely devoted to public information. It is worth noting that in the latter, and in paragraph 1, the use of computer network services is mentioned as a way of providing the public with the appropriate air quality information. In addition, the same article states that the information provided should include 'a short assessment in relation to limit values and alert thresholds and appropriate information regarding effects on health'. Moreover, the so-called 'Air Quality Framework Directive' (96/62/EC) on ambient air quality assessment and management indicates in article 8 that 'plans or programs formulated from appropriate authorities in order to combat air pollution and maintain air quality values within limits in certain heavily polluted urban agglomerations should be communicated to the public'. This same directive also states (in article 10) that when the alert thresholds are exceeded, member states shall undertake measures to ensure that the necessary steps are taken to inform the public. Last but not least, in 1990, a directive regarding freedom of access to information on the environment was put into force (90/313/EEC), aiming to ensure freedom of access to, and dissemination of, information on the environment held by public authorities (Karatzas & Moussiopoulos, 2000b).

Air quality information to be made available to the public may consist of spatial and temporal air quality and emission data, air quality forecasts, measures to decrease personal exposure, guidelines for sensitive sections of the population and administrative details. The APNEE information system will support all these needs and will have the following characteristics (Karatzas & Moussiopoulos, 2000a):

1. the ability to deal with spatial and temporal data;
2. direct and easy access to air quality information;
3. ease of updating air quality-related information;
4. access to online data;
5. provision of easily understood air quality information in a user-friendly manner; and
6. data aggregation functions to modify data according to decision-makers' needs and the needs of the public.

2.2. Dissemination methods

According to a recent study of six European cities, the media used for dissemination are television, radio, newspapers, telephone 'hot lines', Internet, bulletins, street panels and billboards (Daly, 1998). In addition, the results of seven air quality projects within the Environment Sector of the Telematics Applications Programme of the 4th Framework Programme showed that one of the main goals of the AQM (air quality management) systems developed and analysed was to provide air quality information to the public (ENWAP, 1998; examples of AQM systems can be found herein). The implementation of user-friendly media such as TV, radio, newspapers, Internet, info-screens and information kiosks were among the means investigated for the dissemination of air quality information. Web sites were used by most of the projects for communication with the public (Hodges & Koch, 1998), but it should be noted that in the states of the former European 'Union of Twelve', only some 5–15% of households had Internet access—a small audience for electronically delivered public information. Recent statistics show that the percentage of the population having Internet access in Europe varies from 1% (Turkey, May 1997) to 41% (Norway, September 1999). Increasingly, universities, scientific and commercial sites are now well equipped with Internet access, providing an audience for high-quality/in-depth electronic information.

In APNEE, citizens may access the air quality information system through different core information channels based on widely spread, modern information technologies, such as Geographical Information Systems (GIS) on the Web, Wireless Application Protocol (WAP), Short Message Services (SMS) and street panels. In addition, voice servers as well as email will be employed.

2.3. Generalized user requirements studies

There are various possibilities for eliciting user requirements in the field of air quality information systems. Focusing on the Information Society Technologies area in DG XIII programmes, we can extract some interesting examples, which provide us with various options in the area of air quality management systems. Using these, we elaborated a common structure for user requirement questionnaires in order to derive requirements from several institutions with a stake in air quality management or potential services to be based on air quality information:

1. software (types of software);
2. hardware (for air quality applications only);
3. communicating with computers;
4. air quality data;
5. models;
6. visualization of air pollution data;
7. information access modules;
8. SMS automatic alert modules;
9. Web GIS module;
10. WAP module;
11. dynamic voice servers;
12. multimedia file transfer; and
13. electronic panels.

Any user has—in general terms—the possibility of selecting different options corresponding to these 13 user requirement concepts. For instance, in group 1, the user can select between different operating systems, GIS or databases. In group 2, the user has a choice among different types of platforms (Web-oriented or not, etc.).

Following a set of interviews with different institutions, a prioritization process has been conducted in order to compile a ranked list of services for authorities and citizens in APNEE (APNEE Consortium, 2000). This list provides the basis for designing the different air quality services that the environmental administration sites will use to provide information to the citizen.

3. Air quality forecasting systems

Air quality forecasting systems have an important impact on various aspects of daily life in European cities. Since the citizen is not usually familiar with the language of air quality information, it should be provided in a user-friendly form so that the citizen can understand the message and take individual action if necessary. When citizens access air quality forecasting information through the Web or any other communication system (panels, radio, TV, etc.), they should be able to understand the numbers and graphics that the system is providing. The provision of easily understood air quality forecasting system in a city or regional community increases the environmental consciousness of citizens and also provides environmental management operators with a unique tool for presenting environmental information to the public. In addition, environmental city or regional government offices can use the environmental information to take decisions to limit the impact of the forecasted episodes or alarms.

In order to carry out such operations, it will be necessary to run the applications to simulate different emission reduction scenarios. The air quality forecasting system will include an Ozone Transport Assessment Capability (OTAC) to determine those areas in the model's domain that are likely to cause such an episode in the next 24–48 h. These areas identified are immediately investigated in terms of source types (traffic, industrial, domestic emissions, etc.) and these data are used to simulate various different scenarios, thus establishing the best possible emission reduction scenario. This information should be incorporated into the APNEE (GIS, SMS and WAP options) system to disseminate public information on the specific actions that need to be taken, according to the results of the air quality management system. The early warning tool is also useful for implementing emission reduction policies based on immediate and real-time responses (such as traffic reduction in a specific area or for a specific group of mobile vehicles such as trucks or private cars). The combination of an air quality forecasting tool with an OSAT/OTAC capability, scenario analysis and quasi-real-time communication with the citizen (through mobile telephone technologies, etc.) will be central to the future development of air quality management/forecasting tools.

4. APNEE air quality forecasting models

There is a large variety of air quality forecasting models. In recent decades an immense amount of research has been done in this field. Atmospheric flow is a complex matter, the inherently non-linear natural processes being complicated by the turbulent nature of atmospheric flow. Early attempts to model dispersion of pollutants in the atmosphere were made in the late 1960s and early 1970s using very much simplified models (the Gaussian approach) because computer power was quite limited. Nowadays we have the so-called third generation air pollution models which solve the equations governing atmospheric flow much more accurately. When dealing with atmospheric dispersion we have to consider whether the selected tool is appropriate for our purposes; for example, depending on whether we wish to forecast or to study a specific episode in the past. In the latter case, computer time is not a restriction. In APNEE, however, we are interested in 'operational' air quality forecasting models. Hence, computer architecture and a well-balanced combination of different components of the air quality modelling system will be essential.

We also have to remember that there are a set of pollutants called 'criteria' pollutants that figure not only in the scientific literature but also in the air pollution regulations (EPA or European Union). In APNEE, we are particularly interested in these criteria pollutants (SO_2, NO_2, O_3, PM and CO_2). Particular interest has been shown recently in the ozone forecasting since ozone is a secondary pollutant—it is not emitted directly by any emission sources (biogenic or antropogenic) but is created in the atmosphere on a daily basis (afternoon) as a result of atmospheric chemical reactions powered by solar radiation and temperature. Large cities are surrounded by extensive areas with high ozone levels during the summer months on a daily basis. The importance of forecasting these concentrations, particularly the maximum daily ozone levels, with accurate spatial and temporal diaggregation is essential for the development of ozone management strategies by environmental departments in cities around the world. The complexity of these processes is high. In the EPA-454-R-99-009 (1999) document are exhaustive guidelines for developing an ozone forecasting programme. Here, we discuss the advantages and disadvantages of the various forecasting techniques. Among the forecasting methods that can be used are: Persistence, Climatology, Criteria, CART, Regression, Neural Networks, Phenomenological/intuition and 3-D Air Quality Models. A detailed evaluation of these different methods is available in EPA-454-R-99-009 (1999). APNEE employs the CART system and 3-D Air Quality Models. The latter use fundamental atmospheric flow equations and solve them using numerical methods.

Atmospheric and air quality modelling systems usually consist of a comprehensive meteorological model, a coupled transport model, and a chemical model. The set of equations governing them is in general based on conservation principles: conservation of momentum, mass, water and other scalar quantities (e.g. air pollutants), including their chemical transformations. The meteorological (wind, temperature and humidity) fields are predicted using a non-hydrostatic numerical model with terrain-influenced co-ordinates. The model solves the Navier-Stokes system of equations, the continuity equation and any transport equation for scalar as follows:

$$\frac{\partial}{\partial t}(\rho u) + \frac{\partial}{\partial x'}(\rho uu) + \frac{\partial}{\partial y'} + \frac{\partial}{\partial z'}(\rho wu) = -\frac{\partial \hat{p}}{\partial x'} + R_u + C_u \tag{1}$$

$$\frac{\partial}{\partial t}(\rho v) + \frac{\partial}{\partial x'}(\rho uv) + \frac{\partial}{\partial y'}(\rho vv) + \frac{\partial}{\partial z'}(\rho wv) = -\frac{\partial \hat{p}}{\partial y'} + R_v + C_v \tag{2}$$

$$\frac{\partial}{\partial t}(\rho w) + \frac{\partial}{\partial x'}(\rho uw) + \frac{\partial}{\partial y'}(\rho vw) + \frac{\partial}{\partial z'}(\rho wv) = -\frac{\partial \hat{p}}{\partial z'} + R_w + C_w - \hat{\rho} g \tag{3}$$

$$\frac{\partial}{\partial t}(\rho) + \frac{\partial}{\partial x'}(\rho u) + \frac{\partial}{\partial y'}(\rho v) + \frac{\partial}{\partial z'}(\rho w) = 0 \tag{4}$$

$$\frac{\partial}{\partial t}(\rho \psi) + \frac{\partial}{\partial x'}(\rho u \psi) + \frac{\partial}{\partial y'}(\rho v \psi) + \frac{\partial}{\partial z'}(\rho w \psi) = R_\psi + Q_\psi, \tag{5}$$

where: x', y', z': Cartesian co-ordinates; u, v, w: wind velocity components; p: pressure perturbation; t: time; ρ: density; g: gravity acceleration; ψ: any scalar (e.g. potential temperature, θ, or passive pollutant concentration, c); R_u, R_v, R_w, R_ψ: turbulent diffusion coefficients; C_u, C_v, C_w: Coriolis force components; Q_ψ: source or sink terms depend on the transported scalar quantity. (e.g. for potential temperature, this variable includes anthropogenic heat emission and divergence of radiative fluxes).

The usual procedure for mesoscale models states that variables should be split into base-state parts, overline variables, and mesoscale perturbations. We assume here that base-state parts of the wind velocity components are taken as zero. For the thermodynamic variables the separation yields is

$$p = \bar{p}(z') + \hat{p}(x', y', z')$$
$$\rho = \bar{\rho}(z') + \hat{\rho}(x', y', z')$$
$$\theta = \bar{\theta}(z') + \hat{\theta}(x', y', z')$$

The mesoscale pressure perturbation is split into three components:

$$\hat{p} = p_g + p_h + p_{nh} \tag{6}$$

The first term, p_g, corresponds to the large-scale horizontal pressure gradient and the second, p_h, is the hydrostatic part, obtained by mean of hydrostatic equation. By solution of the elliptic pressure equation the non-hydrostatic part, p_{nh}, can be computed implicitly. At this stage several assumptions and approximations are usually made such as: Boussinesq approximation, non-divergent flow assumption, incompressible atmosphere assumption, anelastic atmosphere assumption.

Air quality model simulations are heavily dependent on the quality of the meteorological data. Meteorological data for air quality can be provided either by diagnostic models, which analyse observations at surface sites and upper air soundings, or by dynamic models with or without four-dimensional data assimilation (FDDA). The advection–diffusion equation used by transport models is solved numerically but the numerical methods should be consistent with those used in the meteorological models. When running online models this consistency is guaranteed. The ultimate goal within the atmospheric community is the development of a fully integrated meteorological–chemical model (Seaman, 1995). This is the so-called 'online mode' air quality simulation. There have been a few successful examples of integrating meteorology and atmospheric chemistry algorithms into a single computer program (e.g. San José, Ramirez-Montesinos, Marcelo, Sanz, & Rodríguez, 1995; Vogel, Fiedler, & Vogel, 1995 in a limited mode). For certain research purposes, such as studying two-way interactions of radiation processes, the online modelling approach is needed. Online modelling is also needed for the emission module (Franco & San José, 1999) since biogenic emissions are linked to photosynthetic active radiation and temperature and cold-start emissions (for car traffic flow) are linked to ambient air temperature.

In APNEE, three different air quality forecasting models are used and these are described below.

4.1. The CART system

For the city of Athens for APNEE purposes, the CART method is being used for overall maximum ozone concentration level forecasting. CART (Breiman, Friedman, Olshen, & Stone, 1984) is a Classification And Regression Tree statistical procedure designed to classify data into distinct (or dissimilar) groups. For ozone forecasting, CART enables the development of a decision tree to predict ozone concentrations based on the values of predictor variables that are well correlated with ozone concentrations. CART analysis is actually a binary splitting method that represents one type of tree induction algorithm. It can be described as a nonparametric-data-driven rule-generating algorithm, in the sense that the number of parameters in the final model is not specified beforehand (Gardner & Dorling, 2000). Through a series of 'yes/no' questions concerning database fields, CART automatically searches for important relationships and uncovers hidden structures, even in highly complex data. It identifies the variables with the highest correlation with ozone by splitting the data set into the two most dissimilar groups. The splitting of the data set and tree development continue until the data in each group are sufficiently uniform. Predictor variables used in CART typically include meteorological data (i.e. temperature, wind speed, cloud cover, etc.), but may also include air quality data or other data such as the day of week or length of day. The method partitions a data set into discrete subgroups, based on the value of the dependant variable (here overall daily maximum ozone concentrations). The output from a CART analysis consists of a binary tree structure and associated with each split in the tree is a rule involving one or more predictor variables. To date, the method has reached an index of agreement of more that 85%.

4.2. The AirQUIS modelling system

The Air Quality Information System (AirQUIS) represents the air pollution part of a modern Environmental Surveillance and Information System (ENSIS) developed and demonstrated during the 1994 Winter Olympic Games in Lillehammer, Norway. The AirQUIS system is a user-friendly, map-oriented, complete air quality management system containing modules for online data collection, statistical evaluation and numerical modelling to obtain information, carry out forecasting and plan future air quality.

The AirQUIS system has a menu-oriented, geographical interface and, in addition to statistics and graphical presentation, contains the following modules: online measurements, emission inventory database, atmospheric dispersion models, exposure of materials, and human health. A system of modern online sensors for measuring selected air pollution indicators can be designed specifically for the area concerned. The measurements are automatically transferred from the monitoring sites to a central database for quality control. Data quality control is performed at different levels in the data collection process: in the field during automatic and manual calibration and control, at the central data collection base, and during the approvals and final storage of the database, where simple statistics and data graphics are used to check the validity and representativity of the data.

The emission module is a flexible system containing a user-friendly map-oriented interface for data on pollutant emissions from sources such as industry, traffic and energy (consumption of fossil fuels) and from other mobile sources such as airport and harbour activities. The temporal variation of emissions can be entered specifically for each source or for groups of sources. Based on emission factors, emissions can also be calculated from consumption data. The traffic module is the most complex part of the emission module. It includes road types and façades, vehicle type distribution, traffic time variation and emission factors dependent on parameters such as vehicle type and age, traffic speed and road type.

The models included in the AirQUIS system covers air pollution at all scales (traffic in street canyons and along roads, industrial emissions, pollution from households, etc.) within the urban areas and on a regional scale. NILU developed the source-oriented numerical dispersion model EPISODE (Walker, 1997), which is a combined 3-D Eulerian/Lagrangian air pollution dispersion model for urban and local-to-regional-scale applications. The model may be used to calculate air pollution in an area from several simultaneous emission sources, such as road traffic (line sources), domestic or home heating (area sources) and individual industry sources (point sources). The model produces ground-level, hourly averaged concentrations in building points or specified receptor points. Information can be further presented as gridded data. The system can aggregate the results from hourly averages to user-specified time periods (daily, monthly, etc.).

Based on concentration calculations and population distribution, either gridded or in buildings, estimates of exposure affecting human health can be calculated. These can be related to European or local air quality guidelines or other air quality indicators used for the component considered.

The AirQUIS system is used as an automatic, daily air quality forecasting system in five Norwegian cities. Using 48-h weather forecasts, hourly maps and tables of air quality are produced for the previous 24 h. The number of people exposed to the different levels of air pollution is also presented. The results are automatically transferred to the local authorities to hep with decision-making.

4.3. The OPANA model

OPANA is the operational version of the Atmospheric mesoscale Numerical pollution model for regional and urban Areas (ANA). Fig. 1 shows how the different modules of the ANA system are linked. This model comprises several modules, such as the REgional MESoscale Transport model (REMEST), the CHemical Model for Atmospheric processes (CHEMA), the DEPOsition model (DEPO), the REmote sensing MOdel (REMO), and EMIssion model for Madrid Area (EMIMA).

All these modules are in fact independent models that can be applied for specific purposes. The CHEMA model is integrated with the REMEST model in the 'online' mode; the chemical equations are solved and updated at the same time as the advection and diffusion are simulated by the REMEST model. The EMIMA model is run in 'off-line' mode; the emissions for the simulated days are produced before starting the ANA simulation and stored in a file, which is read by ANA during the simulation. The DEPO model is run in online mode and the REMO model in off-line mode. REMEST and CHEMA are connected in online mode so that the transport numerical algorithms used for the meteorological module can be used for transporting the chemical elements. CHEMA is thus not a chemistry transport

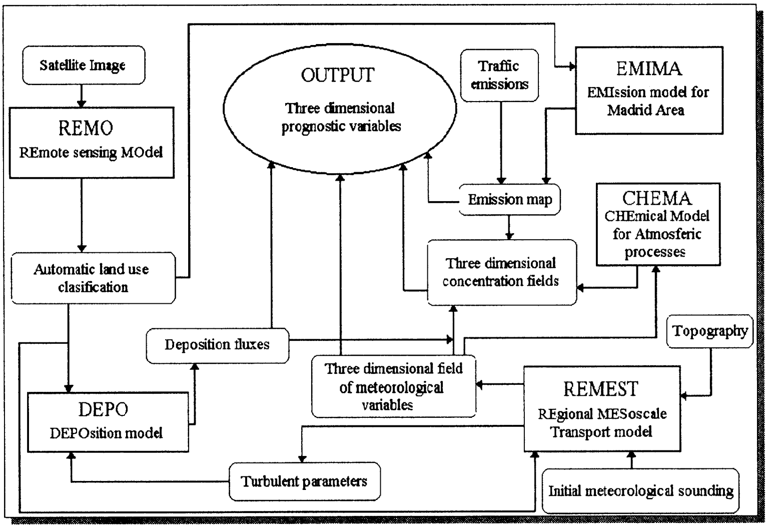

Fig. 1. OPANA system architecture.

model but simply a chemical equation solver. The online connection is limited by the chemistry integration time (1800 s); the chemical equations are not solved at every meteorological time step (the tests showed an increase of about 4 to 6 times in the final CPU time in this mode). This provides a quasi-full consistency in the system. However, in the operational version the emission module (EMIMA) is not linked to temperature and photosynthetic active radiation from the REMEST module, so that an interpolation from a look-up table for a typical year in the region is used.

The OPANA modelling system incorporates a sophisticated visualization tool which contains VIS5D, FERRET, GRADS and OCTAVE applications, all embedded into a Tcl/Tk environment. The whole system can be launched through the Internet using a recently developed tool called WEBPORT.

5. The use of multi-modal communication channels in APNEE

One of the main goals of most of the management systems analysed from the ENWAP group (Environment telematics for Water and Air Pollution management) was to provide air quality information to the citizen. In previous 4th Framework Programme projects, use was made of TV, radio, newspapers (EMMA, EFFECT), kiosks (TEMSIS) and info-screens (Munich). Through APNEE, citizens may access air quality information through different information channels using the World Wide Web, a GIS-based interface based on the concept of smart maps (Peinel & Rose, 1999a, 1999b, 2000) guides the user to relevant air quality information at various levels of granularity. In the mobile world, SMS will be used for active dissemination of early warnings enabled by subscriber services for concerned citizens, such as particular at-risk groups living in or approaching polluted regions.

WAP-based services will provide more sophisticated information in terms of presentation, content and navigation. In city environments, street panels will serve as a public method of informing citizens on forecasted trends. Voice servers will provide information by phone, and email can also be used for active notification.

Using real-time maps for information navigation and exploration means implementing an innovative interaction metaphor (Rose & Peinel, 1996). Since pollution data are merely number based, online conversion and geo-referencing enables intuitive and easy-to-understand dissemination of real-time environmental data. Employing GSM and street panels as well as the Web also establishes an overall accessible service based on the same data stock.

Citizens will be able to subscribe via fixed or mobile phones to an automatic voice or text-based alert system, thus becoming informed in advance about which parts of the city to avoid during certain hours. Being mobile, it is no longer important where the user is located. He or she can ask the system to provide detailed information for the area where he or she is located at the present time. The project will take into account the different needs for information presentation and information content according to the profiles of users accessing the information system.

5.1. Air quality information access before APNEE

A study already conducted by the APNEE consortium consisted of an analysis of the existing information flow and services provided by the cities involved in the project. Fig. 2 shows how air quality information is currently disseminated within the cities. Access to air quality information can be characterized by:

- low interactivity→barrier to information access for citizens;
- little details→difficulties in understanding the meaning of pollution levels and resulting in barriers to take action either to protect people at risk or to combat air pollution; and
- much human intervention in data processing in air quality information→ slowing down of the flow of information.

Further, the following observations have been made:

1. Information provision does not go down to street level to inform citizens which parts of the city to avoid, even though the geographical coordinates of monitoring stations are known (important for the participating cities representing large agglomerations).
2. The Web services do not provide information in an interactive way and background information on interpretation of alert levels and protection methods for citizens are either not detailed or not given.
3. There is no way for citizens to access additional information easily after an alert (e.g. an air pollution hotline). Static voice servers indicate the pollution levels for the current day without giving additional information on interpretation and protection mechanisms.
4. Medical institutions are not automatically informed.

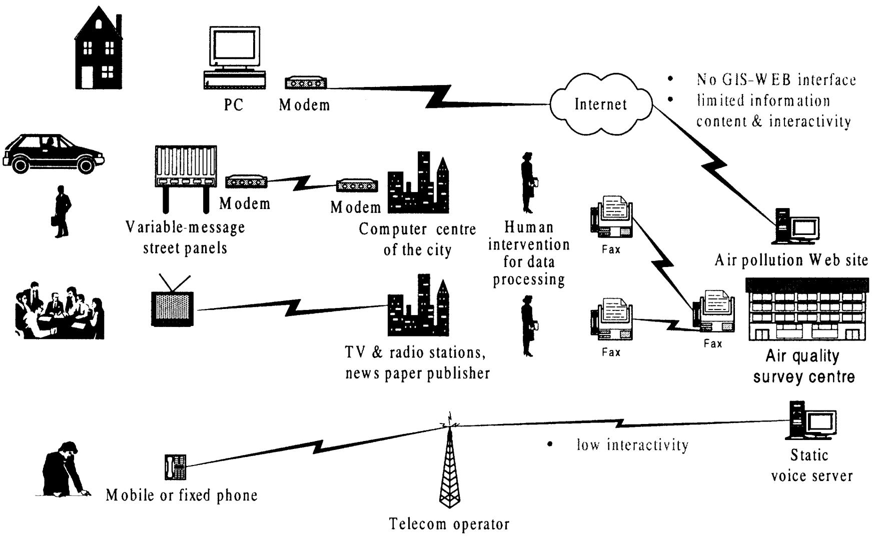

Fig. 2. The situation before the APNEE project began.

5. No dedicated information services are available to allow the most concerned citizen groups to be informed automatically (people with heart problems, asthmatics and elderly, schools, etc.).
6. Early warning and forecasting systems are not yet well known in these cities.

In addition, the APNEE consortium established that there are no online services for professionals and decision-makers that allow the sharing of information in real time and the acceleration of decision-making when an air pollution alert occurs.

5.2. *After APNEE*

Common services for data classification, visualization and dissemination will be provided by the APNEE server, while dedicated local services will reside on their local servers. The APNEE server offers on the one hand a single point of information access with an easy-to-use interface, and on the other hand, dedicated communication and information management functionalities to customize information delivery. A GIS-based mediator classifies incoming streams with regard to spatial location and forecasting methods. Fig. 3 shows how APNEE enhances in particular the information flow through an integrated air quality information system (the part developed by APNEE is indicated in light-grey).

Information access through APNEE will offer new and high-quality levels of services to the citizen:

- high interactivity and reactivity→eliminates access barriers to air quality information and will bring the information directly to the citizens;

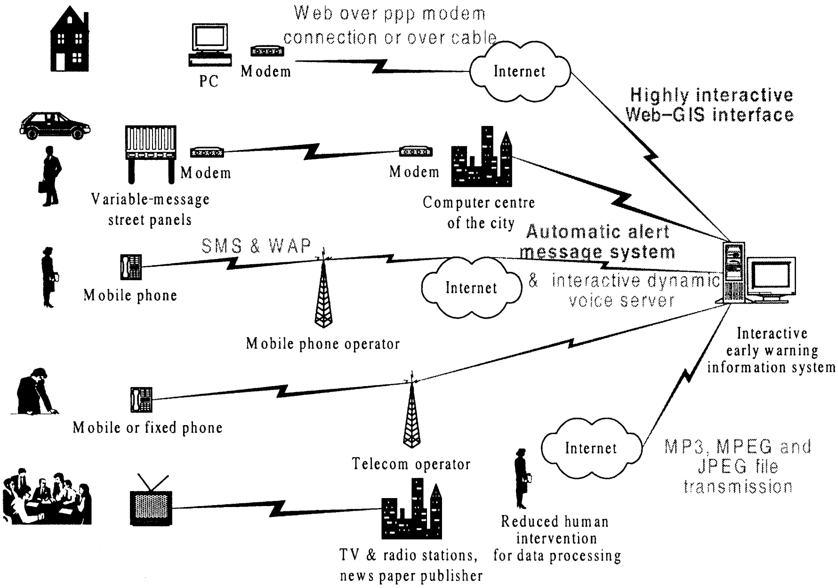

Fig. 3. Air quality information after the APNEE project has begun.

- sophisticated information presentation→easily understood air pollution levels and providing suggestions for actions to protect against and combat air pollution;
- reduced human intervention for data processing→faster information flow and the possibility of acting before air pollution rises to a critical level.

Further, using APNEE, citizens may access the information system through different information channels based on widespread, modern information technologies:

- TCP/IP terminals, either the home or office PC. The only requirement is an Internet connection, since any web browser can be used for this purpose;
- roadside electronic information panels in the city and suburbs;
- mobile phones allowing citizens to receive SMS messages and to access information in an interactive way through voice and WML (HTML for GSM–WAP phones);
- other media (radio, TV and newspapers) will receive and access audio, video and image files in common standard technology formats like MP3 (sound), MPEG (video) and JPEG (image).

6. The APNEE mock-ups

This section describes some interface mock-ups of the future APNEE system with a particular emphasis on the different communication channels that can be used to contact citizens. We define a mock-up as a (usually) full-size scale model of a structure used for demonstration, study or testing. This term is normally used in the engineering industry for design purposes, but fits perfectly in the world of IT technology, since with a visual model users can easily identify and validate the future system in terms of 'look and feel'. Therefore, user feedback can be incorporated at an early stage in system design.

This work will first consider the look and feel of the future APNEE service and will then undergo several iterations during design and development. The images and design studies do not represent a final version of the APNEE system interfaces (service provider interfaces) but merely give a first impression. In addition, adaptations for specific user sites are currently not incorporated. For example, each user site will present its interfaces in the respective local language, and will also want to reflect the respective corporate identity design.

6.1. Mock-up: WWW

The APNEE Web demonstrator will include one European server and four regional servers (local demonstrators) at each project partner's location, as shown in Fig. 4.

The *European server* (or central server) represents the entry portal to air quality information provided by APNEE. The server will contain general information about APNEE and links to related projects. Its main purpose is to guide the citizen towards the regional server. Each of the *regional servers* will mediate between data providers and service providers. Data providers will deliver to APNEE all kinds of pollution data (measured and forecasted) and also warnings, if a pollutant exceeds a threshold. The service providers will offer the information to local city

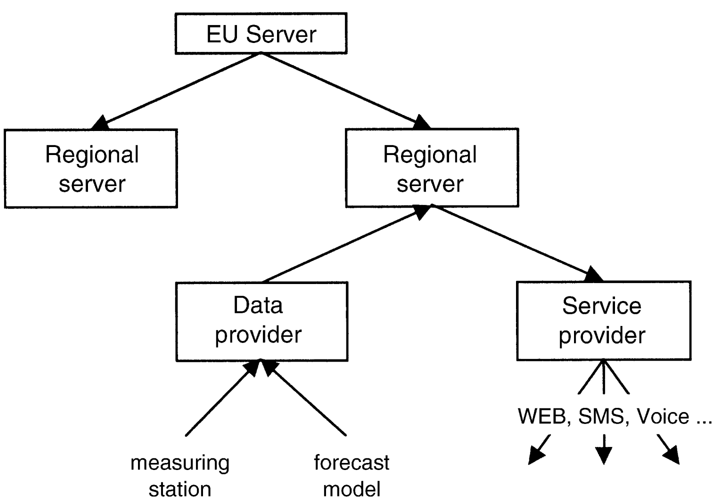

Fig. 4. APNEE server structure: general overview.

authorities and citizens through various kinds of media. The citizen as end-user can either interactively request information, or subscribe to push services to receive daily forecasts or be automatically notified of relevant pollution warnings at his location.

Located at the regional server is the APNEE *database*. This will contain all environmental data, including warnings, and also subscription information, medical advice, pollutant information, and so on. The *data providers* are responsible for collecting data from the measurement network, performing calculations such as forecasts and issuing warnings. These data are then incorporated into the APNEE database. Only quality-assured data from the environmental system databases should be included in the APNEE database. It must contain enough information to provide selected services to the public.

The *service provider* applications should retrieve the information they need directly from the APNEE database. The services for the public could also be run on local (cached) copies of the APNEE database to reduce both the workload on the APNEE server itself and the volume of network traffic. This would also enable a service provider application to store the necessary data in an efficient way for the service provided.

6.2. Mock-up: WebGIS

The APNEE pollution information service will be represented by a so-called WebGIS, that is mapping GIS functions on the Web. The WebGIS client will be implemented as a Java applet. Fig. 5 shows a preliminary sketch of the GUI and how some of the functions will be presented to the user.

Additional features, which will be incorporated at a later stage will include (Fig. 6):

- Showing the region of a city with some layers (themes) selected (e.g. 'city borders', 'municipal districts', 'roads' and measurement stations).
- Overlaying a theme: showing the overlay of the map with measurement stations. Red dots representing the measurement stations are hotspots (sensitive areas), so that placing the mouse pointer or clicking on them will pop up detailed information for the respective station.
- Pop-up menu after clicking on a hotspot: these will comprise station-specific information such as measurement data, instrument description and, if desired, a picture of this measurement station. Furthermore, measurement data will be divided into current data and individual selection. After selecting current data, the measured pollutant levels will be shown below the map.
- Dialogue boxes allowing users to select a particular type of representation: after clicking on the coloured palette located previous to the labelling of the theme a dialogue will be shown. In this dialogue box the user can choose between several forms and kinds of representation. Pressing the *redraw* button will reproduce the chosen representation on the map.
- Graph showing the development of ozone during a certain period: if the user clicks on *individual selection* in the pop-up menu, another dialogue box will be

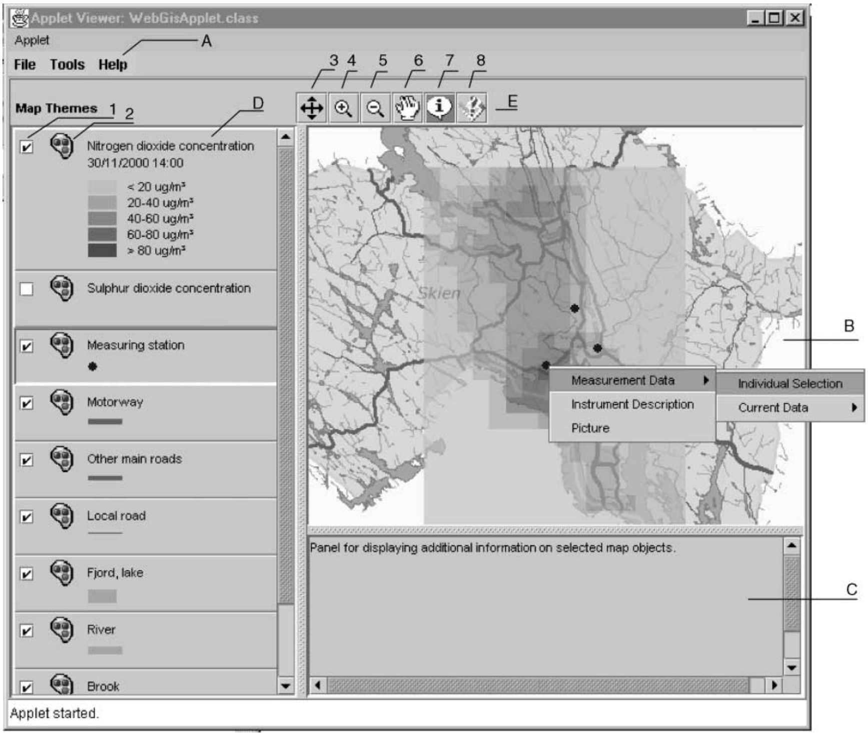

Fig. 5. WebGIS just after the client has started. A, menu; B, map panel; C, information panel; D, legend panel; E, map interaction panel; 1, controlling layer of visibility; 2, modifying of layer content; 3, full extent; 4, zoom out; 5, Zoom in; 6 pan; 7, identify map objects; 8, individual query.

opened, giving the user the opportunity to obtain information about certain pollutants during a certain period. It will also be possible to obtain this information either as a table or a diagram.

6.3. *Mock-up: SMS*

Messages received by email will be daily bulletins and notification on alarms. The maximum length of a message will not exceed 166 characters (longer messages will be divided into shorter ones automatically), which puts an additional stress on keeping the messages short. The following example uses 134 characters.

```
APNEE warning: 15:37, Marseilles/Port Area,
Ozone=190 ug/m3 > 180 ug/m3, avoid driving cars,
avoid physical labour, call 0800123456
```

An example designed for Marseilles (in French) might look like that shown in Fig. 7.

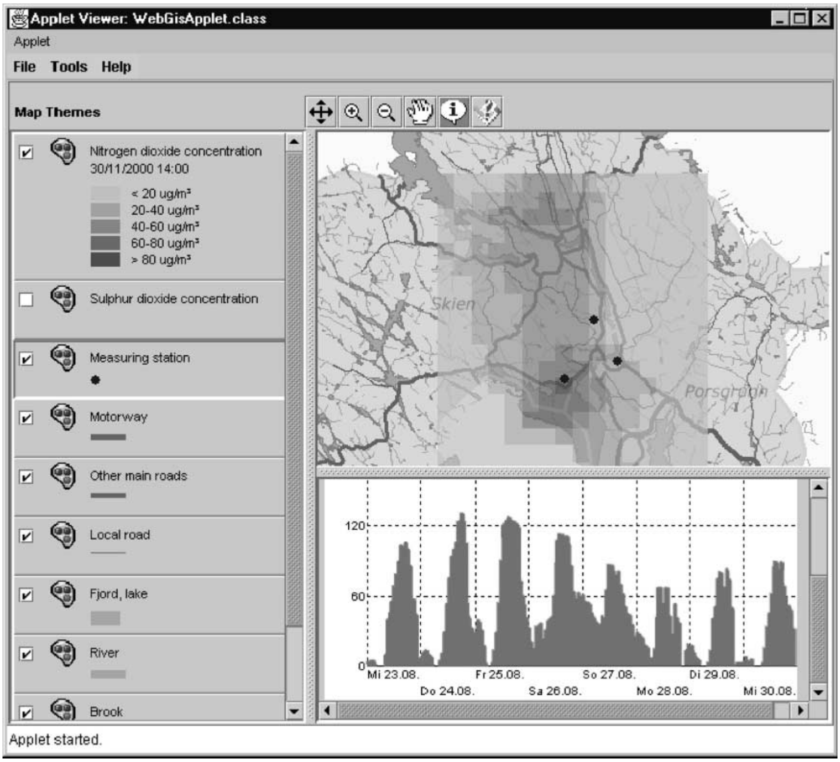

Fig. 6. WebGIS showing ozone levels.

6.4. Mock-up: WAP

The WAP access offers many of the services also offered by the web server. However, most WAP devices only offer a small display and WML has only limited support for graphics. Fig. 8 shows early ideas about the WAP interface for presenting APNEE information. From the APNEE WAP homepage (left) the user can, for example, select the current ozone level, as shown on the right.

6.5. Mock-up: email

The email push service allows information to be sent to subscribed users by email. The messages received by email are daily bulletins and notification on alarms (system failure messages sent to the administrator are too specific to specify in advance or be put here). A sample of the daily bulletin message sent to all subscribers is shown in Fig. 9 and a warning message in Fig. 10.

6.6. Mock-up: street panels

Fig. 11 demonstrates a mock-up of a system of street panels.

POLLUTION OZONE SEUIL D'INFORMATION ATTEINT	Alert description
Pays Aix	Region suffering of pollution
CONSEILS: Réduire vitesse,Prendre transports communs,Eviter sport	Advice

Fig. 7. An example of an SMS alert.

APNEE homepage *Air quality bulletin*

Fig. 8. An example of a WAP interface for APNEE.

7. Conclusions

To date, air quality management has become well established within the scientific community. Systems and services have been designed to address this user community. Yet addressing users at the ordinary citizen level requires easy-to-use interfaces and appropriate presentations for computer illiterates. That is, scientific information about air quality needs to be translated into a form that can be grasped intuitively.

```
This message was sent automatically by the APNEE public server.

Tuesday 2000-07-25, 15:37

Air quality bulletin for Marseilles:

      -   general good conditions in downtown
      -   ozone 80-120 ug/m3

      -   some inconvenience expected in the port area
      -   CO 65 ug/m3 might exceed the limit of 60 ug/m3
          please avoid driving cars in this area
          asthmatics please avoid physical labour
      -   dust 20 mg/m3, limit 10
          asthmatics please avoid physical labour

For more information please visit APNEE at
www.apnee.eu/messages/24335
```

Fig. 9. A typical email daily bulletin message.

```
This message was sent automatically by the APNEE public server.

Tuesday 2000-07-25, 15:37

Air quality notification for Marseilles/Downtown:

      -   CO is 65 ug/m3 exceeding the limit of 60 ug/m3
          please avoid driving cars in this area
          asthmatics please avoid physical labour

For more information please visit APNEE at
www.apnee.eu/messages/24335
```

Fig. 10. A typical warning message sent to users who register for alarm notification.

APNEE plans to provide these intuitive interfaces by capitalizing on the characteristics of various communication channels. The new communication technologies will also allow authorities to implement air quality directives and EU legislation effectively.

In this article, we have presented an outline of the most important and innovative approaches to air quality information systems fostered in APNEE. The strategic combination of air quality forecasting models, air quality network data and new information technologies (Internet, mobile phones, SMS, etc.) will produce the means for giving significant added value to air quality information for European environmental city administrators since it will become possible to implement EU directives related to air quality limits (EU/April, 1999, AQ directive). Special emphasis will be put on the powerful integration of new communication technologies and air quality models. In addition, from a citizen and city administration's point of view, the increase in the quality of air pollution information and the way this information is delivered to the citizen will improve quality of life and provide

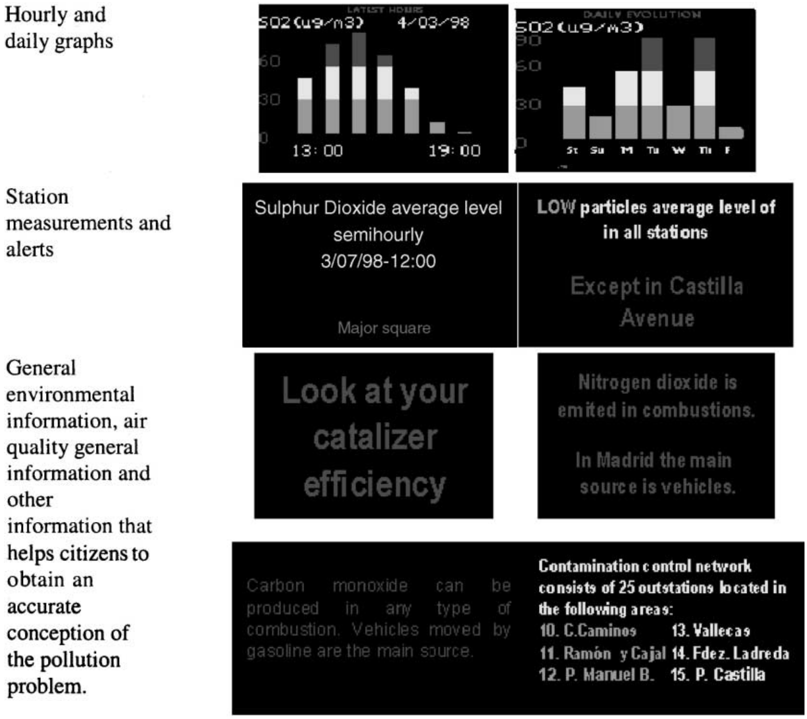

Fig. 11. Street panel mock-up for air quality information.

much better communication and mutual understanding between citizens and city authorities.

APNEE also advances the use of forecasting methods in elevating the quality of information. Until now, air quality models—in both forecasting and scenario modes—have allowed one to determine the contribution of each area in the model's domain to the ozone peak values in forecasting mode (next 24–48 h). The new capability will enable a city environmental administrator to focus on those areas having a major impact on the ozone peaks.

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