On-line Air Quality Monitoring and Warning Support System for Bucharest Urban Area

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Abstract

Air quality is a major issue for all the important cities in the world. Bucharest is no exception. The air pollution in Bucharest, due to traffic and industry, is abundant, especially in areas the human population is concentrated. The fast rate of economic growth is bringing more sources of air pollution. In this context, the AIRAWARE project, funded in the EU LIFE framework, is aiming to build a pilot air quality monitoring and forecasting system to ensure a sustainable development of the rapidly expansive urban areas in Bucharest, minimizing and preventing the air pollution impact on human health.

The AIRAWARE system has a distributed architecture with dedicated sub-systems for: (1) air quality monitoring; (2) numerical modeling and forecast; (3) geospatial portal for data integration, visualization, query and analysis; (4) slow-flow and rapid-flow feedback. The GIS sub-system, described in detail in this paper, is build entirely with standard compliant free and open source software applications like GDAL, Geoserver, PostgreSQL + Post GIS, OpenLayers, TileCache.

The AIRAWARE system users list include the main local and national authorities in the domain of air quality monitoring, forecasting, air pollution abatement and mitigation of impacts, such as: the National Meteorological Administration, the Regional Environmental Protection Agency of Bucharest, the Direction for Public Health of Bucharest, the Centre for Urban Planning of Bucharest, the Institute of Biology of the Romanian Academy and Meteo-France as strategic European partner.

1.   Introduction

Air quality is a major issue for all the important cities in the world. Bucharest is no exception. The air pollution in Bucharest, due to traffic and industry, is abundant, especially in areas the human population is concentrated. The fast rate of economic growth is bringing more sources of air pollution.

In this context, the AIRAWARE project, funded in the EU LIFE framework aims to address multi-targeting awareness of air quality impacts, with a high component of feedback on prevention and

mitigation actions by creating an on-line geospatially enabled system. The system aggregate informations related to air quality monitoring and forecast, impact survey, pollution cadaster, pollution indicators (bio-indicators, human health indicators). Responsible authorities, which are part of the system (the National Meteorological Administration - NMA, the Regional Environmental Protection Agency of Bucharest - REPA-B, the Direction for Public Health of Bucharest - DPH-B, the Centre for Urban Planning of Bucharest - UMPC-B, the Institute of Biology of the Romanian Academy - IB-RA), are expected to use the system as a decision support tool for short and long term sustainable urban air quality management.

Technically, the AIRAWARE on-line system was designed following a distributed architecture. All the partners and end-users are able to access the system using a thin web client (via a simple web browser like Internet Explorer or Mozilla Firefox) or a thick desktop client, to store, display, query, analyze and retrieve Bucharest air quality related information's (Figure 1).
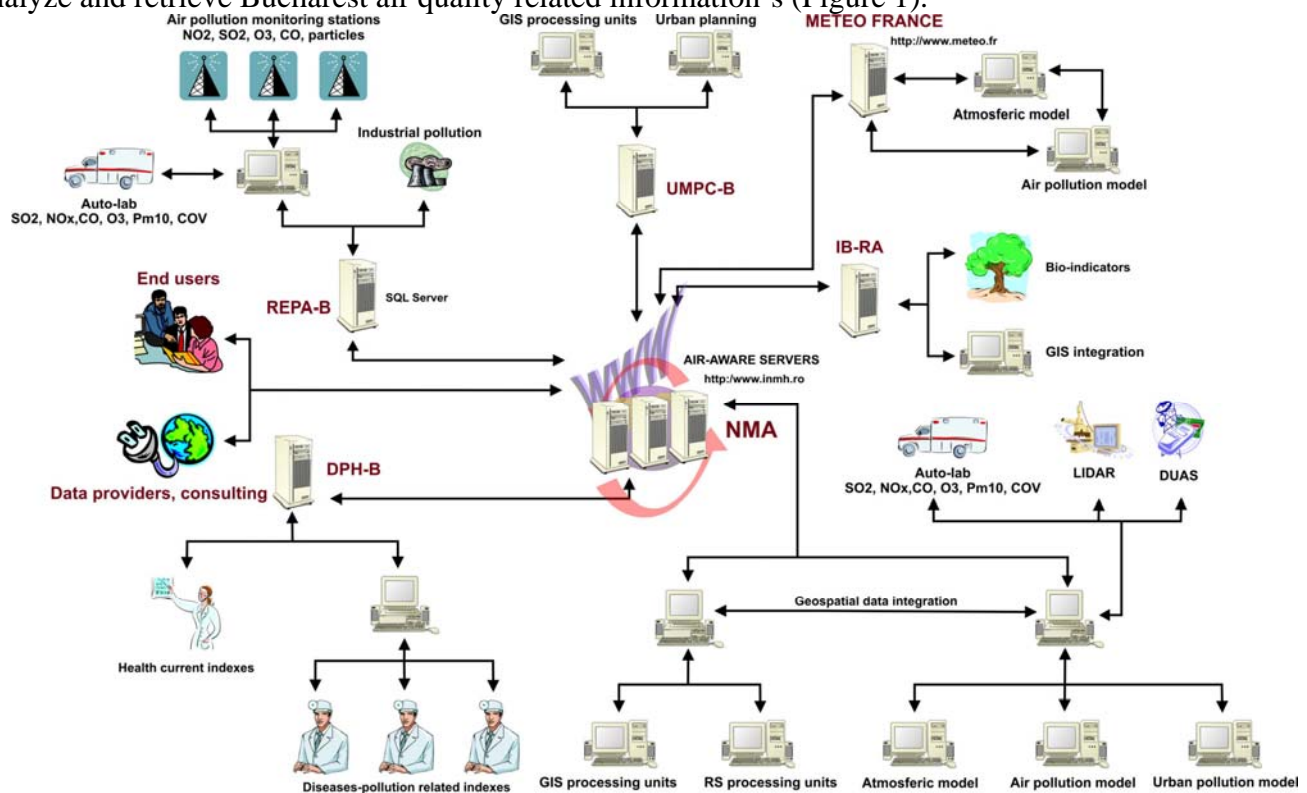

Figure 1. AIRAWARE on-line system flowchart

The main functions of the system are:
- acquisition, validation, storage, spatial analysis and data interpretation;
- management and exchange of raster and vector graphic information, and also of related attribute data for the air quality monitoring activities;
- handling and preparation for a data rapid access;
- information updating (temporal modification);
- data restoring, including the elaboration of thematic documents;

- generation of value-added information;
- distribution of the derived products, forecasts and warnings to the interested authorities, media, etc.

2. Air quality component

2.1 Air quality monitoring sub-system

Includes fixed ground monitoring stations measuring the most important pollutants (NO2, SO2, O3, PM10, PM2.5, Pb, benzene, CO), mobile laboratories and a complex LIDAR/DIAL spatial measurement of emission/ambient air contamination data, allowing both 3D modeling of diffusive, non-point source emissions, as well as a complex 3D spatial ambient air contamination information.

2.2 Numerical modeling and forecast subsystem

Involves chemical processes, transport and dispersion of pollutants for a complex, real or forecasted state of the atmospheric boundary layer. The sub-system depicts the 3D air pollutant "hat" evolution for various time ranges anticipation, from few hours to 3 days, while the larger scale forecasted trajectories provide climatological behavior estimates for pollutant transport over the urban and peri-urban areas of Bucharest. Several mathematical models are link together to provide the described functionality: ALLADIN (a limited area version of the ARPEGE spectral global model for numerical weather forecasting), TEB (simulates turbulent surface fluxes for urban areas for a given complex representation of urban surface), MEDIA (a French 3D Eulerian model for short, medium and long range transport of pollutant in the atmosphere), MOCAGE (a French global three dimensional chemistry and transport model), OML (a modern Gaussian plume model, based on boundary layer scaling) and OSPM (a semi-empirical model of street canyon flow and dispersion).

The forecast model outputs two main types of data: regularly distributed grids and pollutant trajectories, both in plain ASCII and binary file formats. In order to make use of this data in the AIRAWARE GIS based system, some conversions and data adaptation need to be performed. Detailed procedures were elaborated for each type of output from the model (E.g. wind forecast, temperature forecast, pollutant concentration etc.). Operations like file format conversion, data repreojection and interpolation were chained together using the Python powerful programming environment.

3. Geospatial component: AIRAWARE geoportal

A geospatial portal is a human interface to a collection of online geospatial information resources, including data sets and services (OGC, 2004). The AIRAWARE geoportal represent the public face of the AIRAWARE on-line system, created to facilitate the sharing of air quality geospatial data and knowledge.

3.1 Open source GIS

The Free and Open Source GIS (FOSS) space includes products to fill every level of the OpenGIS spatial data infrastructure stack (Ramsey, 2007). The main advantages of FOSS software are (1) the availability of the source code and the right to modify and use the software in any way; (2) not tied to a single vendor; (3) big community to support; (4) good security, reliability & stability; (5) very good standard compliancy; (6) lower implementation cost.

The entire AIRAWARE geoportal and back-end modules are based on the existing FOSS and FOSS4G applications.

3.2 Data fusion and routing

The system needs to handle different types of spatial geo-data (scanned maps, satellite images, vector files, digital elevation models, model outputs) in different file formats and coordinates system (Stereographic 1970 – official Romanian coordinate system, Gauss-Kruger, UTM – Universal Transverse Mercator), processed by the project partners on different computing platforms and software environments. To make all the work easily available to the participants and end-users, a detailed specification package, mostly based on GDAL/OGR libraries, has been developed and implemented into a central application. These ensure the fact that every piece of information is correctly parsed and represented into the portal (Figure 2).
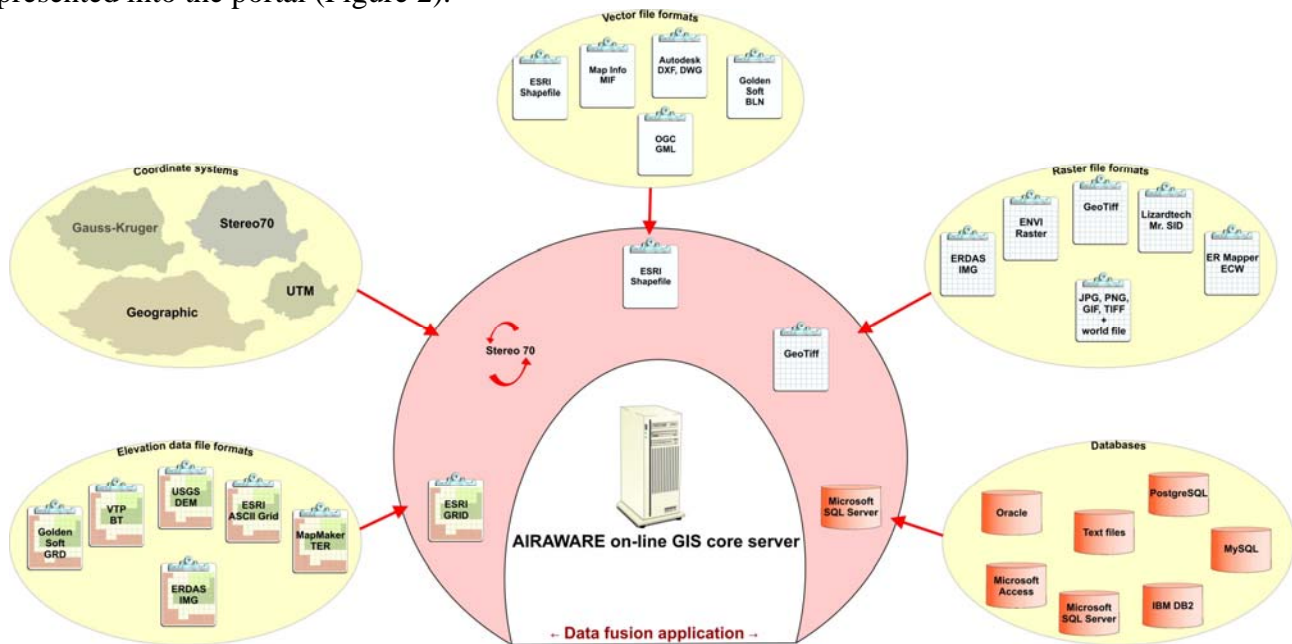

Figure 2. Data fusion and routing application

The application is also able to automatically route the data from the project participants to the system (mainly the mathematical models) and to webmapping application. For this purpose, a Task and Stay Resident (TSR) application was constructed.

When a project participant send new data to the system, a configuration file is created. The TSR application constantly checks the configuration files. When changes are detected, the application forward the new file (through FTP connections) to the appropriate processing application or mathematical model. The TSR application wait for the output file to be created and notify the users to check the results. If necessary, more processing steps are initiated.

The TSR has been constructed such that it is able to monitor every 10 seconds for the arrival of a triggering file. Multiple request can be simultaneous handled. All the performed operations and recorded in a file log. Based on this log, the users and project partners are able to track the system activity and to detect any malfunctions.

3.3 Portal structure

The content is managed by Textpattern, a powerful and flexible, open source content management (CMS) application. For supplementary, specific functionality, custom modules were built. Other free applications are providing server-side functionality: MySQL (relational database management system), PHP, Python, Java (server-side scripting languages), Apache (webserver), Tomcat (servlet container), phpMyAdmin, phpPgAdmin (web clients for database management).

For geospatial data management, top open source applications were also integrated in the website: PostGIS (geospatial data storage), GeoNetwork Opensource (geospatial data catalog and metadata editor), Geoserver (standard geospatial server for serving data via WMS and WFS), OpenLayers (client webmapping application), TileCache (Python-based WMS/TMS server, with pluggable caching mechanisms and rendering backends).

The information flow between the various server side application and the front end graphical interface is determined by the interaction with the portal users and their requests (Figure 3).
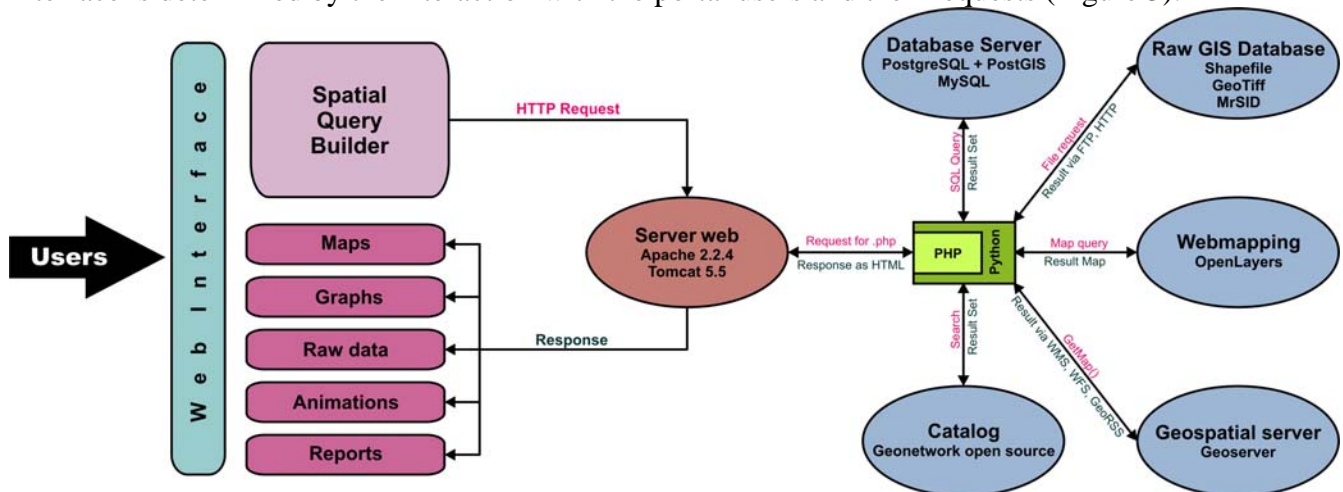

Figure 3. Portal information flow

3.4 Portal interface

The website interface was carefully designed, respecting the existing W3C (World Wide Web Consortium) standards and separating the structure from the presentation by using strict XHTML markup and CSS (Cascade Style Sheets). New web technologies, like AJAX (Asynchronous JavaScript and XML), were also used to increase the interactivity. The goal was to obtain a simple, friendly and accessible environment for air quality data management. From the user's perspective, when a button is clicked, an operation is performed, and a result appear on the screen. This summarizes a complex process of communication between the viewer and the server.

The portal is divided in several functional sections. Each section contains a predefined type of information. The most important one is the map section. Here the users can view and explore the cartographic representation of the spatial data stored in the GIS database. Both Raster and Vector (points, lines or polygons) data can be displayed in this area. The map can also include labels for the represented spatial entities, generated based on the related database attributes. The cartographic symbols and labels are automatically adjusted according with the representation scale. The map is refreshed after each action performed by the user. The geospatial information, represented as map layers, can be divided in two categories:

(1) the background database, represented by typical GIS data (street network, buildings, river network, landuse, points of interes, DEM, satellite data). Additionally to the GIS database developed within the AIRAWARE project, the users can chose to display OpenStreetMap, Google Maps, Yahoo Maps or Microsoft Maps as background data.

(2) air quality related data, like mathematical model outputs (e.g. meteorological forecast: temperature, pressure, wind speed & direction etc.; pollutant forecast concentrations: PM10, CO, NO, NO_2, SO_2, O_3, Benzene), pollution measured status, bio and health indicators.

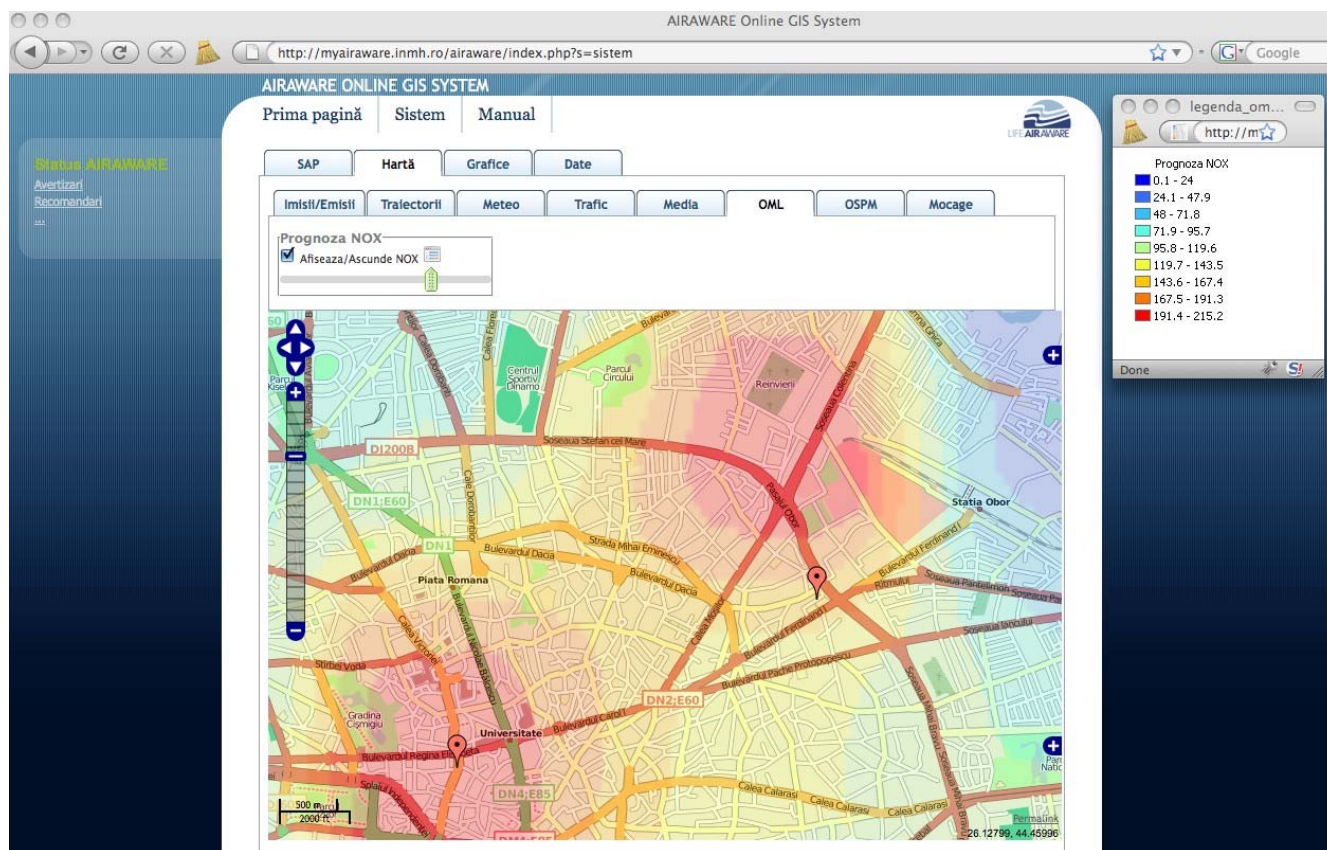Examples of the map section graphical interface is presented in figures 5 and 6.

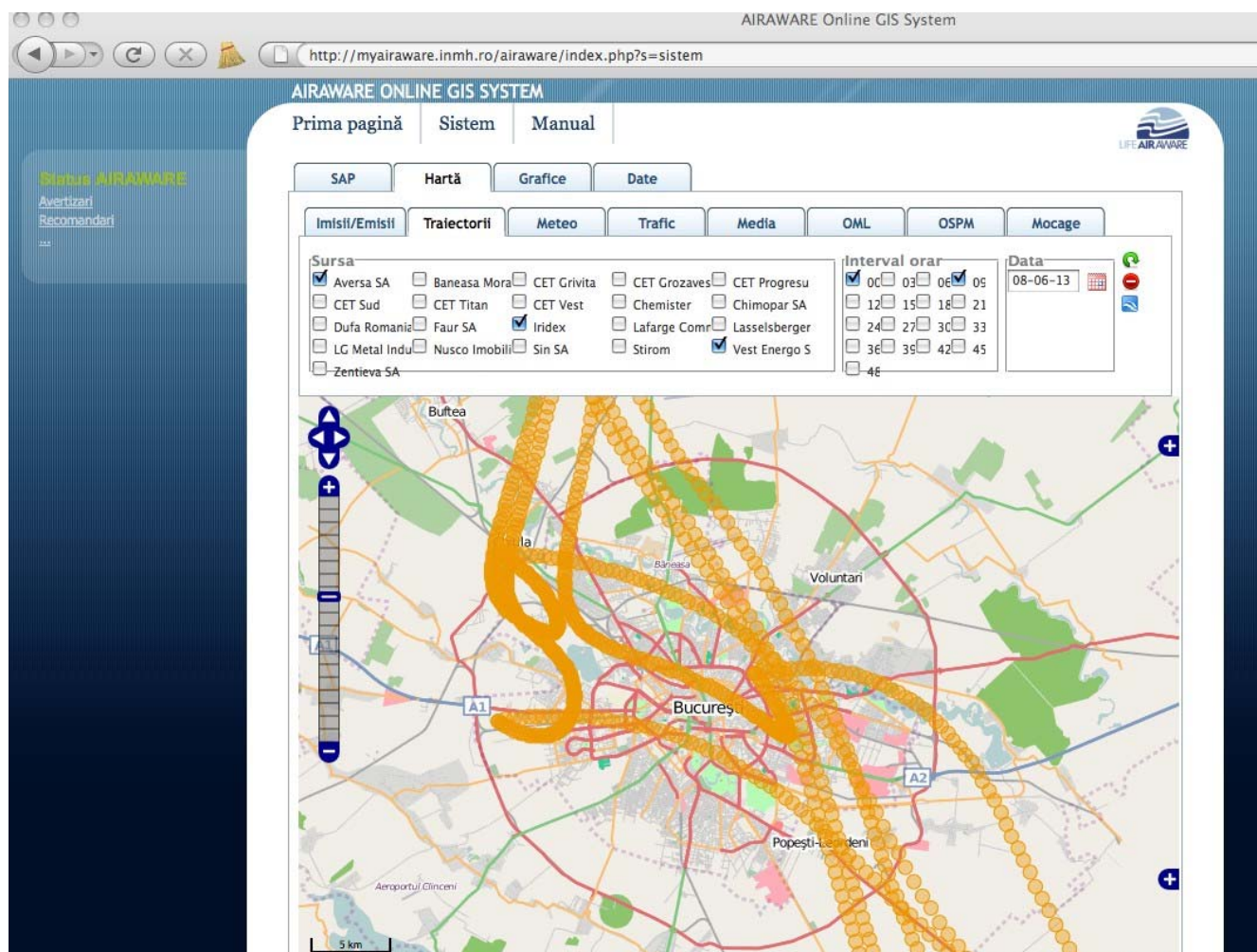Figure 5. NOX concentration forecast displayed using the AIRAWARE system

Figure 6. Pollutant trajectories forecast displayed using the AIRAWARE system

The users with who require more advanced GIS functionality or want to use their own data processing algorithms can access the AIRAWARE system content using a desktop (thick) client. This is possible due to the standard data access protocols and methods implemented on the AIR-AWARE server-side. Also, the users with poor or zero GIS knowledge are able to access some of the AIRAWARE products within popular, easy to use, applications like Google Earth.

Other sections on AIRAWARE portal allow the user to display the air quality informations as graphs (Figure 7), tables or download the source data in popular file formats as ESRI Shapefile, KML (Keyhole Markup Language), MS Excel, CSV (Coma Separated Values).
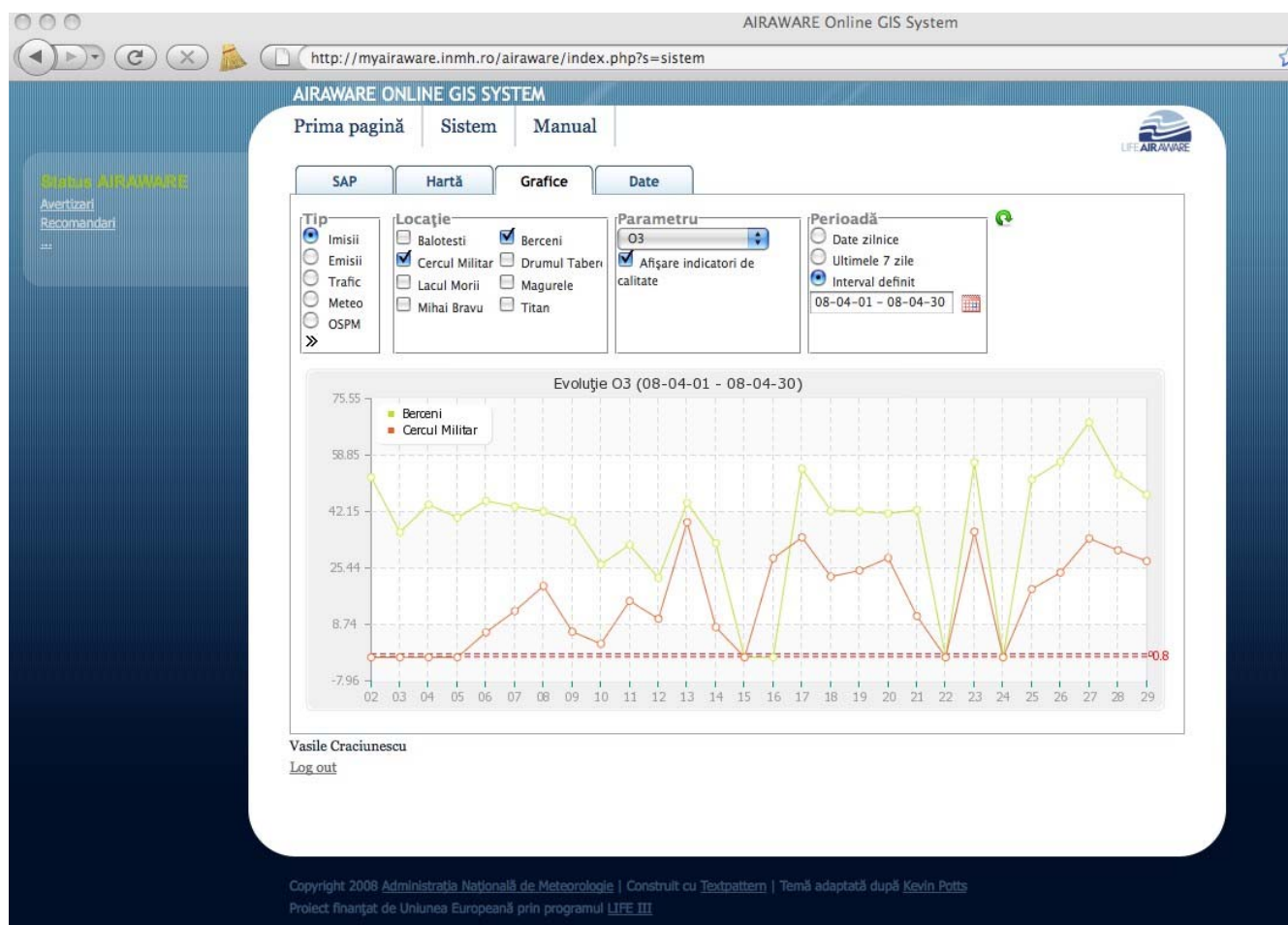
Figure 7. April 2008: O3 recorded values at two monitoring stations

4.   Conclusions

The domain of free and open source geospatial applications is growing fast and provide reliable solutions for all the stages of geodata management. The FOSS4G plays an important role in adaptation of GIS technology by stimulating new experimental approaches and by providing access to GIS for the users who cannot or do not want to use proprietary products. The construction of the AIRAWARE system proved that possibility to build a complex system using only standard compliant, free and open source software, thus lowering the implementation costs and increasing portability and chances for large scale adoption.

The AIRAWARE system is currently in testing phase. The operational version is expected to be available in December 2008.

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