Real-time air quality assessment and management: cascading models in a web based implementation

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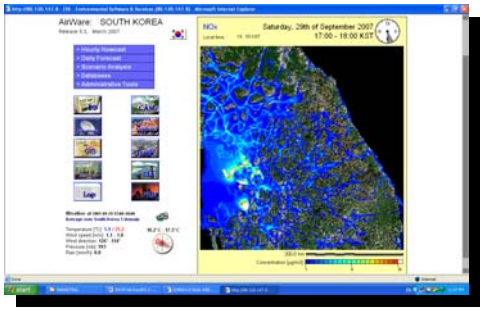
Abstract

For the assessment of regional to local air quality in urban and industrial areas, a system of coupled models (AirWare) that cover several levels of nesting from regional (several hundred kilometers) to city level and street canyons has been developed in EUREKA E!3266 WEBAIR. The main objectives are to support regulatory tasks, compliance monitoring, and public information, and to provide a reliable basis for the multi-criteria optimization of emission control strategies to effectively and efficiently meet a range of environmental standards. Examples from Tehran, Iran, and Seoul/Gyeonggi-do, South Korea are used to demonstrate the system operation and performance. We compare two very large cities with different physiographical and socio-economic structures, management objectives, and policy options, yet a common problem. A web based implementation where all functions are accessed by a standard web browser provides ease of use for all major actors and stakeholders including public information functions. The system includes daily forecasts (meteorology and air quality) for 3 to 7 days, and hourly now-casts with data assimilation. In parallel to forecast and now-cast runs, the system supports interactive scenario analysis for EIA and emission control optimization tasks. The simulation tools include MM5 and WRF for meteorological forecasts based on downscaling global (GFS) weather forecasts, and dynamic emission modeling. The models are linked to several data bases (monitoring data and emission inventory) and an embedded GIS. CAMx is used for photochemistry and particulates, AERMOD for conservative substances. A high-resolution convolution model with a near-field mixing zone is based on AERMOD as a computational kernel for city-wide line sources and local

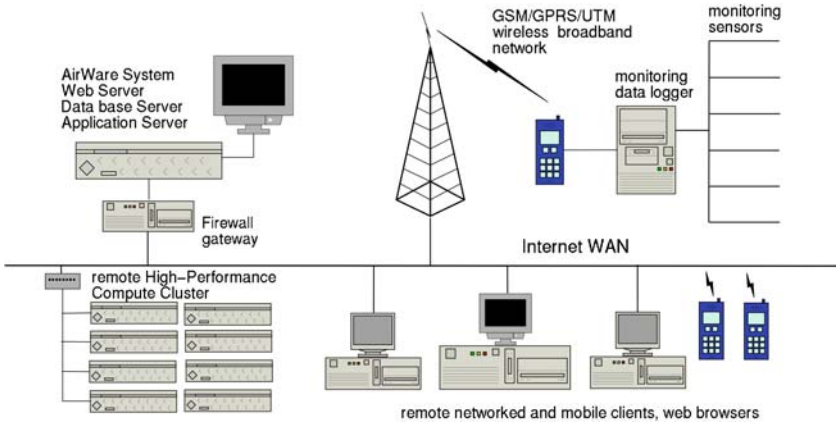
concentration gradients with allows for near real-time simulation of thousands of road segments. Additional models include a 3D FD code for street canyons with explicit building obstacles for selected hot-spots, and a stochastic implementation of CAMx for probabilistic ozone forecasts.

OBJECTIVES AND |FUNCTIONS: a central objective of the AirWare system is to support monitoring and regulatory compliance (e.g., with the European Union Air Quality Framework Directive 96/62/EEC); this includes an important public information component that is extended by daily forecast of up to 7 days, as well as probabilistic forecasts using the 3D photochemical code CAMx both with an ensemble of meteorological forecasts, and assumed PDF around the major emission sources and their dynamics. Results are shown as color coded map overlays for current or forecast ambient concentrations, or air quality indices such as PSI, CAI, APMI, incorporating moving averages and maxima for several substances over longer periods. The series of multi-day forecasts at any given date is also available as an animation of hourly ambient concentration plots over the background map, formatted as an mpeg movie. Beyond monitoring and forecasts, AirWare includes tools for data analysis (emissions, monitoring) and several analytical functions. These support scenario analysis (WHAT IF … questions), direct comparison of scenarios, and impact assessment, as well as optimization task (HOW BEST TO …) : for each emission source or class of emission sources one or more alternative or additive emission control technologies can be assigned with it respective (piecewise linear) costs functions for annualized investment and operational costs. A combination of Monte Carlo, adaptive heuristics and machine learning, and genetic algorithms, and a discrete multi-criteria DSS as post-processing tool then allocates and scales technologies to

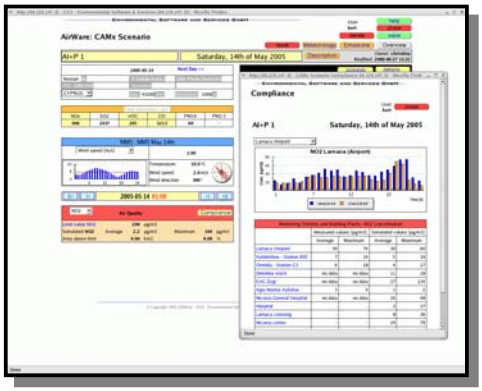


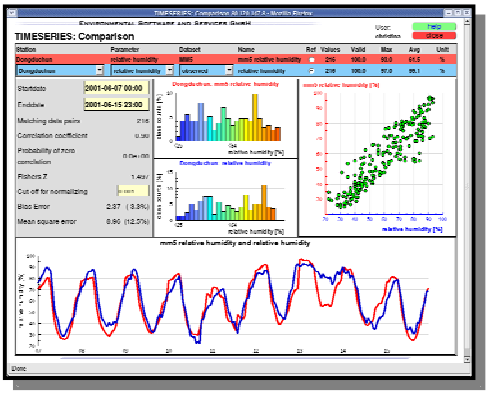
design a set of pareto-optimal solutions given a set of user defined constraints on environmental and economic performance criteria. A similar tool finds optimal location for monitoring stations given a series of long-term (annual) model runs at hourly resolution and a preference structure for the monitoring.

COMPONENTS AND IMPLEMENTATION: Beside the model supported monitoring and public information, AirWare offers data bases and analysis tools for emission sources, including dynamic emission modeling; monitoring data analysis for both historical data sets and the real-time data acquisitions; a data base of emission control technologies used for the optimization; and an embedded GIS that manages distributed models input data such as DEM, land cover, but also population distribution for exposure analysis. The primary models in AirWare are the prognostic meteorological models MM5 and WRF, that generate high-resolution meteorological fields to drive the air quality models. The central model is the 3D nested-grid photochemical code CAMx (in Korea, Anyang University uses CMAQ in parallel), and AERMOD for regulatory applications, long-term (annual) impacts assessment, and a high-resolution convolution version with a mixing zone representation of streets and the near-field gradients from traffic sources. For larger individual point sources under transient conditions and very short time steps, (e.g., boiler start-up) we use a version of (multi)PUFF, Lagrangian transport of a Gaussian plume. Finally, for very high-resolution near field representation where building obstacles have to be treated explicitly, a CFD code (TIMES-URBAN) developed in collaboration with the Russian Academy of Sciences, Institute for Mathematical Modeling, is used. These models obtain their input data "automatically" from dynamic emission models. The models in turn use an emission data base and emission scenarios, generated for any arbitrary spatial model domain and model period, using historical data, data observed in real-time,



or data generated (forecasted) with temporal patterns from average emission values. AirWare is implemented as a distributed client-server system, that integrates several "logical application servers", remote information resources (monitoring networks as well as high-performance cluster computing for demanding simulations and forecasts), and supports distributed users through any networked device that supports standard web browsers or the MMS/WAP protocol for mobile clients such as smart phones or PDAs.





TEST APPLICATION EXAMPLES: Within the international EUREKA E!3266 WEBAIR RTD project (http://www.ess.co.at/WEBAIR), several parallel test cases are used to develop and validate the system. They include: the Island Republic of Cyprus and a several urban scale case studies, e.g., Limassol. Cyprus has comparatively low emissions, but complex meteorology due to its island nature; the Korean peninsula, with the Seoul metropolitan area and the surrounding heavy industry province Gyeonggi-do; the Greater Tehran Area around the capital city of Iran, a case that is dominated by traffic sources; the industrial city of Sisak in Croatia; and selected industrial development zones along the Arabian Gulf, United Arab Emirates. Experiments with real-time data assimilation are just starting, but the comparison with historical data shows very good correspondence of model results with observational data for both meteorological and photochemical air quality model results.

The on-line pilot systems and operational forecasts are accessible from http://www.ess.co.at/DEMOS#air, and the WEBAIR and AirWare project sites: http://www.ess.co.at/WEBAIR and http://www.ess.co.at/AIRWARE