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URBAN AIR SYSTEM: AN OPERATIONAL MODELLING SYSTEM FOR SURVEY AND FORECASTING AIR QUALITY AT URBAN SCALE

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Abstract: The URBAN’Air System, developed by NUMTECH with the support of ADEME (Environment and Energy French Agency), is an operational modelling platform allowing to monitor and forecast air quality over urban areas. Based on the modelling code ADMS-Urban (McHugh *et al.*, 1997), it allows to map the pollution level (NO_2, C_6H_6, SO_2, O_3, PM_{10} and $PM_{2.5}$) at very high resolution (from the street scale to the great urban areas).
As input, the system requires mainly meteorological data, background pollution, and detailed emission inventory. Meteorological and pollution input data can be either observed for the “monitoring” or “scenario mode”, or modelled at larger scale (using regional model) for the “forecasting mode”. This operational system is launched automatically every day, and performs high resolution maps of air quality index from day-1 (past) until day+2. It allows also to perform scenarios studies, on a long meteorological period. This system already works in several French cities (Strasbourg, Mulhouse, Orléans, Clermont-Ferrand).
In this presentation, we will focus on the deployment of the system over Aix-en-Provence, Strasbourg and Clermont Ferrand. The system takes into account traffic emissions (with temporal profiles), residential emissions, industrial sources, local airport, and biogenic emissions. The dispersion code was tested and the results compared to measurements (passive devices and automatic stations) performed by French AASQA (Agreed Association for Air Quality Monitoring). The validation of the model includes both comparisons with long term measurements (yearly average concentrations) and hourly data. The system works on its “forecasting mode” over Strasbourg and Mulhouse, and is still under testing for Aix-en-Provence. The abilities of the model to forecast every day, hourly concentrations for the next 48 hours are verified. Coupled with regional platforms such as AIRES (MM5/CHIMERE) and PREV’AIR, the system allows to reproduce with a good agreement the concentrations close to the traffic, as well as the urban background levels.

Key words: *air quality, urban scale, operational modelling system, ADMS-Urban*

INTRODUCTION
In most cities, air quality has strongly improved over the past decades. The visible pollution has been reduced from many cities due to local, national and European initiatives. Occasionally air quality represents a human and an environmental threat during industrial incidents or pollution episodes (photochemical episodes, traffic emissions). In many European cities air quality is a concern. From several years ago, missions of air quality agencies have consisted of both monitoring in real-time the majority of air pollutants that may impact human health and environment, and forecasting air quality. Air quality forecasts are realized both to inform people about the air quality that will be expected in the next days and to take preventive measures of reduction of pollutant emissions associated with industries and road transport.

The URBAN’Air System (UAS), developed by NUMTECH with the support of ADEME (Environment and Energy French Agency), is an operational modelling platform allowing to monitor and forecast air quality over urban areas. It combines local data on traffic patterns, weather forecasts and mesoscale chemical forecasts. These data are input to the ADMS-Urban pollution dispersion modelling system, which allows to map the pollution level (NO_2, C_6H_6, SO_2, O_3, PM_{10} and $PM_{2.5}$) at a high degree of spatial resolution (from the street scale to the great urban areas). This system already works on several French cities (Strasbourg, Mulhouse, Orléans, Clermont-Ferrand), and is currently being installed in other cities of the PACA region (Armengaud *et al.*, 2010).

The present document is related with the application of the UAS for Aix-en-Provence, Clermont-Ferrand and Strasbourg. We focus on the following points:

- The deployment of the system for the diagnostic estimation and the forecast;
- The performances of the system in terms of ground-level concentration predictions and air quality indexes, focusing both on mean annual estimations and on restitution of pollution peaks.

The paper is structured as follows. In section 2, a general overview of the UAS will be given. The section 3 is about the adjusting approaches realized for each application and a few results. The sections 4 and 5 concern results for the diagnostic mode and for the forecasting mode including maps and performances of the system. Some conclusions and perspectives will be given in section 6.

GENERAL OVERVIEW OF URBAN AIR
In this section, a brief review of the main functionalities are presented. The application has been developed to monitor and forecast pollution levels and air quality index (AQI). The calculation of pollutant concentrations is performed using ADMS-Urban (Mc Hugh *et al.*, 1997; Carruthers *et al.*, 2000). Every day, the system is launched automatically, and performs high resolution map of air quality index for day-1 (past) until day+2. In case of a scenario mode, the system also allows to realize scenarios studies for a long meteorological period.

The simulation domain is often subdivided into different grids, which comprise regular and intelligent gridding. In case of Clermont-Ferrand and Aix-en-Provence, domains comprise 2 grids. Such a methodology allows to optimize the computation time keeping a high resolution in the vicinity of main sources as roads. As input (Figure 1), the system requires meteorological data, background concentrations and detailed emission inventories. Emissions are often extracted from inventories developed by French AASQA. Inventories mostly contain emission rates, temporal profiles and source characteristics for different activities including point sources (industrial sites), lines (roads), areas (natural sources), volumes (residential sources) and grids (more diffusive sources). Meteorological and pollution input data can be measured for the scenario mode, or modelled using mesoscale models for the forecasting mode. For Aix-en-Provence, meteorological and pollution data are derived from AIRES forecasts conducted at 3 km grid spacing over the Bouches-du-Rhône region for the predictions at D to D+2, and surface station observations at D-1 provided by Meteo-France and the Atmo PACA network. Some specific meteorological data as the Monin Obukhov length, not directly available by mesoscale models, was considered as input data for UAS. The Monin Obukhov length was derived from available meteorological output data of MM5: sensible heat flux, potential temperature and friction velocity. Background concentrations used for dispersion simulation are determinated by 2 methods: a combined method based on wind components and pollution concentrations, as well as a statistical method based on pollution concentrations. Preliminary surveys have shown that inventories often tend to underestimate measured PM_{10} concentrations. This last method allows to perform ADMS-Urban simulations for PM, and is especially used as an operational tool by AIRFOBEP (Brocheton *et al.*, 2010).

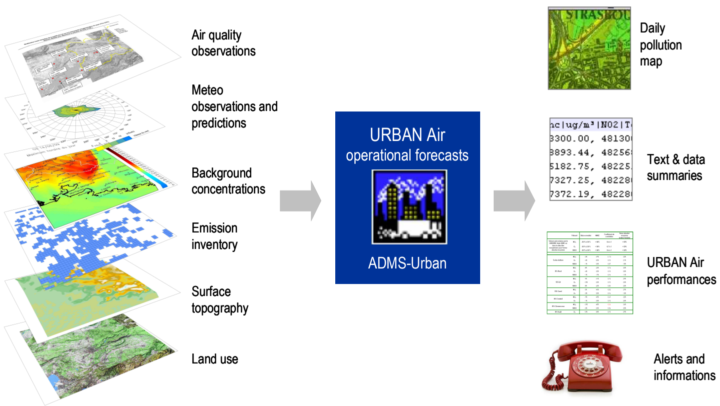

Figure 1. Overview of the functioning of the UAS.

DEPLOYMENT AND ADJUSTING

The deployment of the UAS is usually driven as follows. Firstly, scenario studies are realized for a long meteorological period to determine the best configuration of the system. Doing this, adjusting methods are involved (Figure 2), including sensitivity tests and evaluations of the system by comparison with continuous and occasional measurements from AASQA networks. These surveys generally allow to adjust emission data, model parameters and calculation grids. Secondly, for the operational mode, adjusting is also conducted for meteorological and pollution data produced by regional platforms (AIRES, PREV'AIR…).

In Figure 2, the step 1 consists in a first statistical validation using common statistical indicators, such as the bias, the root mean squared error (RMSE) and the correlation coefficient. Statistical results constitute decision support tools to perform the system or not (step 2). The step 3 concerns system modifications according to expertnesses. Repeating the method described (step 1 to 3) for different configurations of the system makes up sensitivity tests.

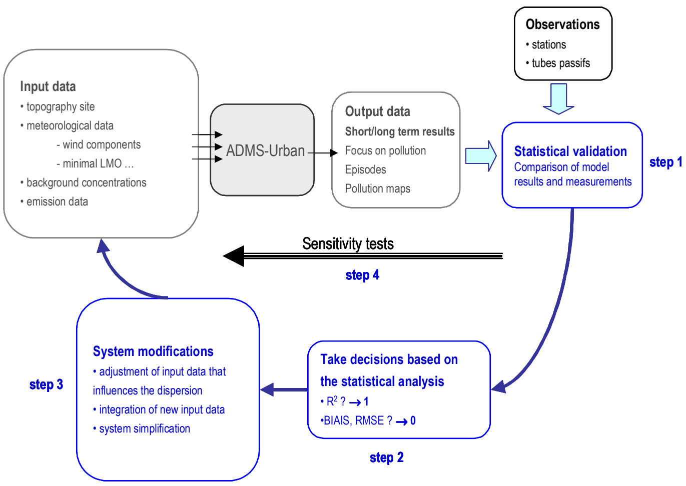

Figure 2 Overview of the adjusting phase

Configurations of the system are compared using various statistical methods, such as the comparison of obtained normalized indicators for a long period. Another method allows to bring to light the best predictions between scenarios, by comparison of ground based measurements and UAS results hour by hour. This last method is driven as follows. Firstly, the best prediction between configurations is saved hour by hour: the best prediction corresponds to the smallest absolute bias. Secondly, for all the simulation period, the proportion of good prediction associated to each configuration is estimated.

To illustrate it, results in Figure 3 show the best predictions between different configurations. In Figure 3a, results concern the effect of meteorological scenarios on the restitution of NO_2 levels for 3 urban stations, for a period ranging from the 1st January 2007 to 31st December 2007. Results of the scenario 4 correspond to the effect of preventing the atmosphere from becoming very stable (related to the urban heat island effect), that give best predictions. The Figure 3b presents the proportions of best prediction for NO_2 forecasts (from D until D+2) for 4 urban stations between 6 configurations, which combine meteorological and pollution data from regional models. The configurations **sc22** and **sc32** give 25% of the time the best results of NO_2 forecasts. These configurations include mesoscale pollution data established according to wind directions. These results show the difficulty to retain one configuration and a priori the interest to consider results from a set of configurations.

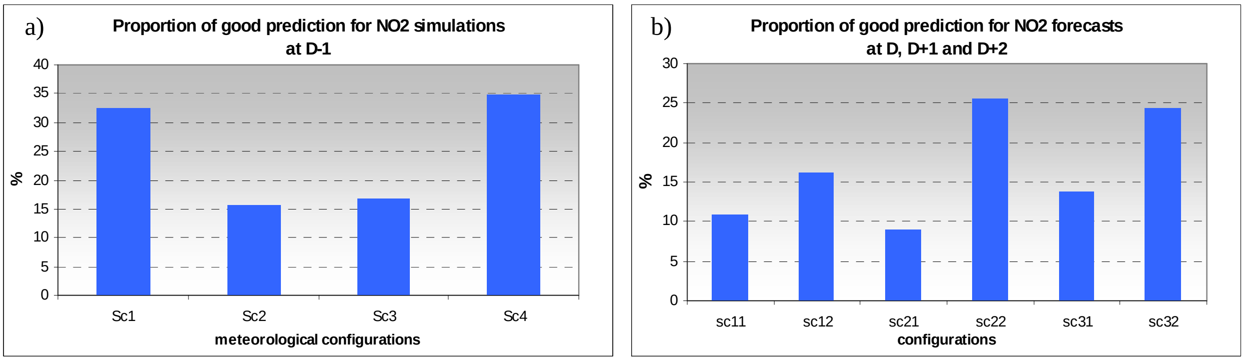

Figure 3. Comparisons of configurations. (a) For the diagnostic mode, proportions of best prediction between meteorological scenarios based on simulations for 3 urban stations from the 1st January 2007 to 31st December 2007. (b) For the forecasting mode, proportions of best prediction between combined meteorological and pollution scenarios based on forecasting simulations at D to D+2 for 3 months of simulations and for 4 urban stations.

USING URBAN AIR AS A DIAGNOSTIC TOOL

In this section, an air quality map and some quantitative evaluation of the results for a diagnostic use are presented.

The Figure 4 presents examples of air quality maps for Aix-en-Provence and Clermont-Ferrand. Such maps with high resolution allow to identify sensitive zones over a small region. In Figures 4a and 4b, local zones are clearly impacted near roads and cities. More results of the Aix-en-Provence area are available at: *http://www.atmopaca.org/html/aide_descision_CPA.php*

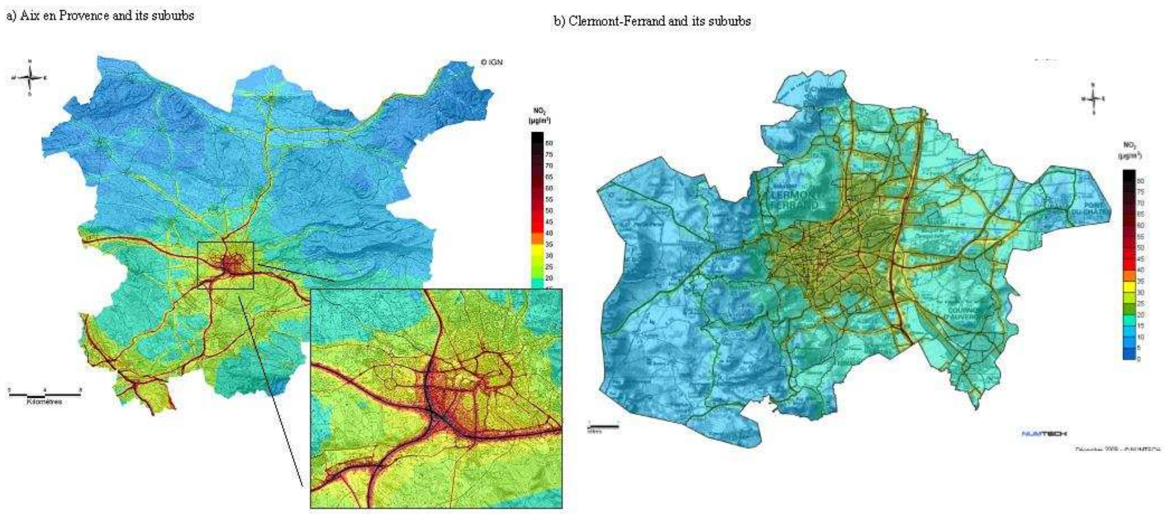

Figure 4. Mean annual concentrations of NO_2 over Aix-en-Provence and its suburbs (CPA) as well as the Clermont-Ferrand area produced by UAS.

The Figure 5 gives an example of correlation and bias for NO_2 over Aix-en-Provence and its suburbs in October 2007. The comparison of simulation results with measurements by passive samplers is satisfying with a bias of –1.28 µg/m^3 and a good correlation. This result shows the good capacity of the model to reproduce the spatial distribution of pollution levels.

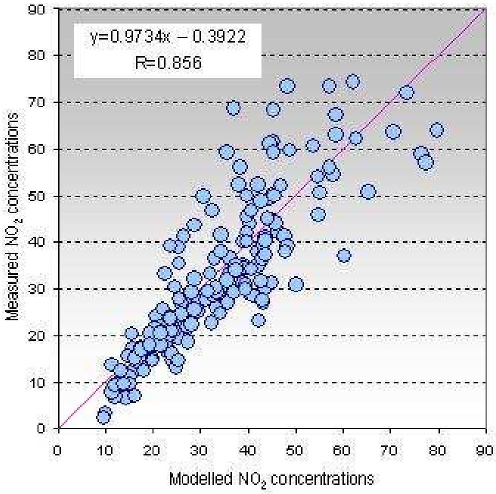

Figure 5. Example of correlation and bias for NO_2 over Aix-en-Provence and its suburbs (CPA). October 2007.

USING URBAN AIR AS A FORECASTING TOOL

This section presents air quality map and quantitative evaluation of the results over Strasbourg (ASPA, 2009) and Aix-en-Provence (system still under development). The UAS which is currently operational over the Rhine area produces daily air quality maps of the air quality index as well as the indexes of ozone, NO_2 and PM_{10}. An example of air quality maps produced by the platform is presented on Figure 6. Daily operational results are available at:
http://www.atmo-alsace.net/site/modelisation/urbanair/index.php?ville=strasbourg

Figure 6. Overview of the UAS deployed for the Strasbourg area (source: ASPA).

The quantitative evaluation of the results concerns daily results for a period ranging from 2007 to 2009 over Strasbourg (ASPA, 2009). As the Aix-en-Provence platform is still under development, any quantitative results will be shown for few months. The Table 1 displays the average results taking account of all measurement surface stations. The Table 1 presents the proportion of good prediction of the air quality index and other pollutant indexes: the modelled index is equal to the measured index or is really close (more or less one index). For all systems, results are very satisfying for AQI, O_3 and NO_2 with more than 70% of good prediction (more or less one index).

The Figure 7 presents a comparison between UAS and AIRES results for a few testing months for 4 urban stations. For all simulation dates, results are more satisfying with UAS than mesoscale predictions, especially for NO_2 indexes due to high resolution near main emitters (roads). The proportion of good prediction is always higher for UAS than for AIRES. The Figure 7b focuses on observed pollution peaks (index > 5), results for NO_2 and AQI are really satisfying with ADMS. Actually, PM_{10} results for both UAS and AIRES are less satisfying. PM_{10} exceedances are observed but not simulated by UAS, which is clearly due to pollution data from AIRES.

Table 1. Proportions of good prediction (%) for one year for Strasbourg (ASPA, 2009) and few months in 2010 for Aix-en-Provence, with UAS

				AQI	O_3	NO_2	PM_{10}
D	Strasbourg	2009	calculated index = measured index	47	68	44	38
			calculated index + / - 1 to measured index	86	99	90	80
	Aix-en Provence	2010	calculated index = measured index	24	49	31	7
			calculated index + / - 1 to measured index	67	94	75	30
D + 1	Strasbourg	2009	calculated index = measured index	50	63	39	33
			calculated index + / - 1 to measured index	83	98	89	78
	Aix-en Provence	2010	calculated index = measured index	30	47	34	7
			calculated index + / - 1 to measured index	72	94	76	32
D + 2	Strasbourg	2009	calculated index = measured index	48	63	38	38
			calculated index + / - 1 to measured index	85	97	89	80
	Aix-en-Provence	2010	calculated index = measured index	24	51	33	7
			calculated index + / - 1 to measured index	71	97	76	32

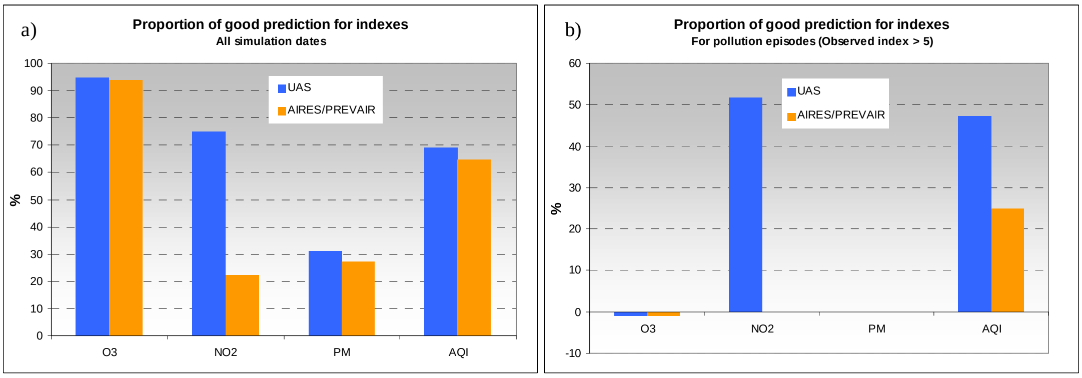

Figure 7. Comparison between UAS and AIRES which gives the proportions of good prediction (%) to reproduce indexes at more or less 1. (a) all simulation dates, about 3 months of simulations, (b) during observed pollution episodes (indexes more than 5). No observed ozone episode was observed.

CONCLUSIONS AND FUTURE WORK

In this paper, the operational modelling system UAS for survey and forecasting air quality at urban scale was presented, as well as the deployment of the system over several cities. Coupled with regional platforms such as AIRES (MM5/CHIMERE) or PREV'AIR, the system allows to reproduce with a good agreement the concentrations close to the traffic, as well as the urban background levels. UAS results are really satisfying, and they show that UAS is able to perform better for monitoring and forecasting pollution levels over urban areas and then to complete regional air quality platforms. In this framework, NUMTECH works in close cooperation with AASQA in order to test and improve the UAS.

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