PREV'AIR : an operational system for air quality monitoring and forecasting over Europe

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THE PREV'AIR SYSTEM, AN OPERATIONAL SYSTEM FOR LARGE SCALE AIR QUALITY FORECASTS OVER EUROPE; APPLICATIONS AT THE LOCAL SCALE

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INTRODUCTION

Numerical simulations of pollution events with deterministic models have become easier for the last decade thanks to increasing computer skills. Hence three-dimensional chemistry-transport-runs can be performed on a single workstation for long-term simulation or real-time forecast over large scale areas. Furthermore, fast Internet download and high file storage capacity in data processing make it possible to use a wide database of meteorological parameters and pollutant concentration measurements.

The PREV'AIR system rests on those technological progresses for delivering daily air quality forecasts in operational conditions. In function since summer 2003, it is the visible part of a wider collaborative project - the PREV'AIR project - launched by the French Ministry for Ecology and Sustainable Development (**MEDD**), aiming at: (1) providing technical support on atmospheric pollution management in Europe, in the framework of negotiations on trans-boundary air pollution[2]; (2) providing large scale national air quality information based on numerical simulations and observations. The PREV'AIR system is a complementary monitoring tool with respect to the local information delivered by the French qualified associations in charge of regional air quality monitoring (AASQA[3]). It relies on a chain of numerical tools: air quality simulation models, modules ensuring the provision of meteorological and air quality input data to these models, modules enabling the extraction and use of the numerical data computed by the system. The outputs of the PREV'AIR system (secondary pollutants forecasts and maps) are archived to build up a large scale air quality simulation database over Europe.

The following public organisations are involved in the PREV'AIR project:

- **INERIS** (National Institute for Industrial Environment and Risks) is a public institution, under the supervision of the MEDD. Its mission deals with assessment and prevention of accidental and chronic risks due to industrial plants, chemical substances and underground operations, towards health effects and environment. Within the PREV'AIR project, INERIS is in charge of developing the PREV'AIR architecture, delivering daily information about air quality; providing and archiving air quality data produced within the PREV'AIR system. The institute also participates to the development of the CHIMERE model in collaboration with the IPSL (see

[2] This is done through technical programs related to the CAFE (Clean Air For Europe) project managed by the European Commission, and to the Convention on Long-Range Trans-boundary Air Pollution of the United Nations - Economic Commission for Europe.

[3] In France, since December 1996, air quality monitoring has been ruled by the Law on Air and Rational Use of Energy. About 40 qualified associations are in charge of air quality monitoring all over the French territory.

hereafter). Moreover INERIS carries out air quality studies for the MEDD including reporting and prospective analysis.

- **IPSL** (Pierre-Simon Laplace Institute) is a research institute in the field of environment, under the supervision of the National Centre for Scientific Research (**CNRS**). IPSL ensures the development of the chemistry-transport model(s) - the CHIMERE model(s) - used within the PREV'AIR system.
- **ADEME** (Agency for Environment and Energy Management) is a public institution under the supervision of the Ministries in charge of research, ecology and energy. It helps implementing public policies in the field of energy and environment at local, national and international levels. ADEME ensures the gathering, archiving and transmission of real-time air quality data locally collected by the AASQA. By this way, ADEME builds up the BASTER database used by the PREV'AIR system.
- **Météo-France** joined the system in 2004. The organisation develops another air quality model, MOCAGE, and ensures its operational implementation for the needs of PREV'AIR.

The MEDD financially supports the PREV'AIR project through the funding of INERIS activity.
The PREV'AIR system is briefly presented hereafter, as well as the first conclusions drawn from two years of operation.

ARCHITECTURE OF THE PREV'AIR SYSTEM, INPUT DATA AND OUTPUTS

The PREV'AIR system provides daily air quality forecasts at three spatial scales. Global forecasts are produced by Météo-France with the chemistry-transport model MOCAGE and transferred every day to the PREV'AIR system. Continental and national forecasts are computed by the chemistry-transport model CHIMERE implemented in the PREV'AIR forecasting chain. In the "continental" set up, pollutant concentrations are computed over Western Europe with a 50 km*50 km resolution. In the "national" set up, pollutant concentrations are computed over France with a 10 km*10 km resolution.

Ozone and nitrogen dioxide forecasts have been delivered for two years. In october 2003, forecasts were extended to particulate matter. PM10 are assumed to be composed of sulfate, nitrate, ammonium, primary particles, anthropogenic and biogenic secondary species. The aerosol module accounts for 6 bins from 10 nm to 40 µm. From spring 2005, PM10 account for desert dust, sulfates and carbonaceous compounds advected from the domain boundaries. A specific emission module have been built to account for soil particles emitted from erosion and resuspension processes. Each day (D), hourly concentration levels are predicted over a four-day period going from D-1, 00h UT to D+3, 00h UT. The first 24 hours of forecast are actually rather simulations whereas the next 72 ones are strictly speaking forecasts. The meteorological predicted fields necessary to run CHIMERE are obtained in two steps: 1. Low resolution meteorological forecast data are downloaded from the ftp server of the American National Weather Services, where they are produced by the Global Aviation Model (AVN) model; 2. High resolution meteorological forecast data are then locally computed using the MM5 model.

Emission data come from the EMEP program[4], with hourly, weekly and monthly temporal profiles from IER[5]. Contrary to meteorological data that change from day to day, emission data are set once and for all.

[4] Co-operative Program for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe
[5] Institut für Energiewirschaft und Rationelle Energieanwendung, University of Stuttgart

Observed air quality data are also used by the PREV'AIR system (see hereafter). They are transmitted by various European organisations. For example, the French real-time air quality data are downloaded from the BASTER ftp server and used both to evaluate the model skills and to correct *a posteriori* the CHIMERE air quality (D-1) simulations.

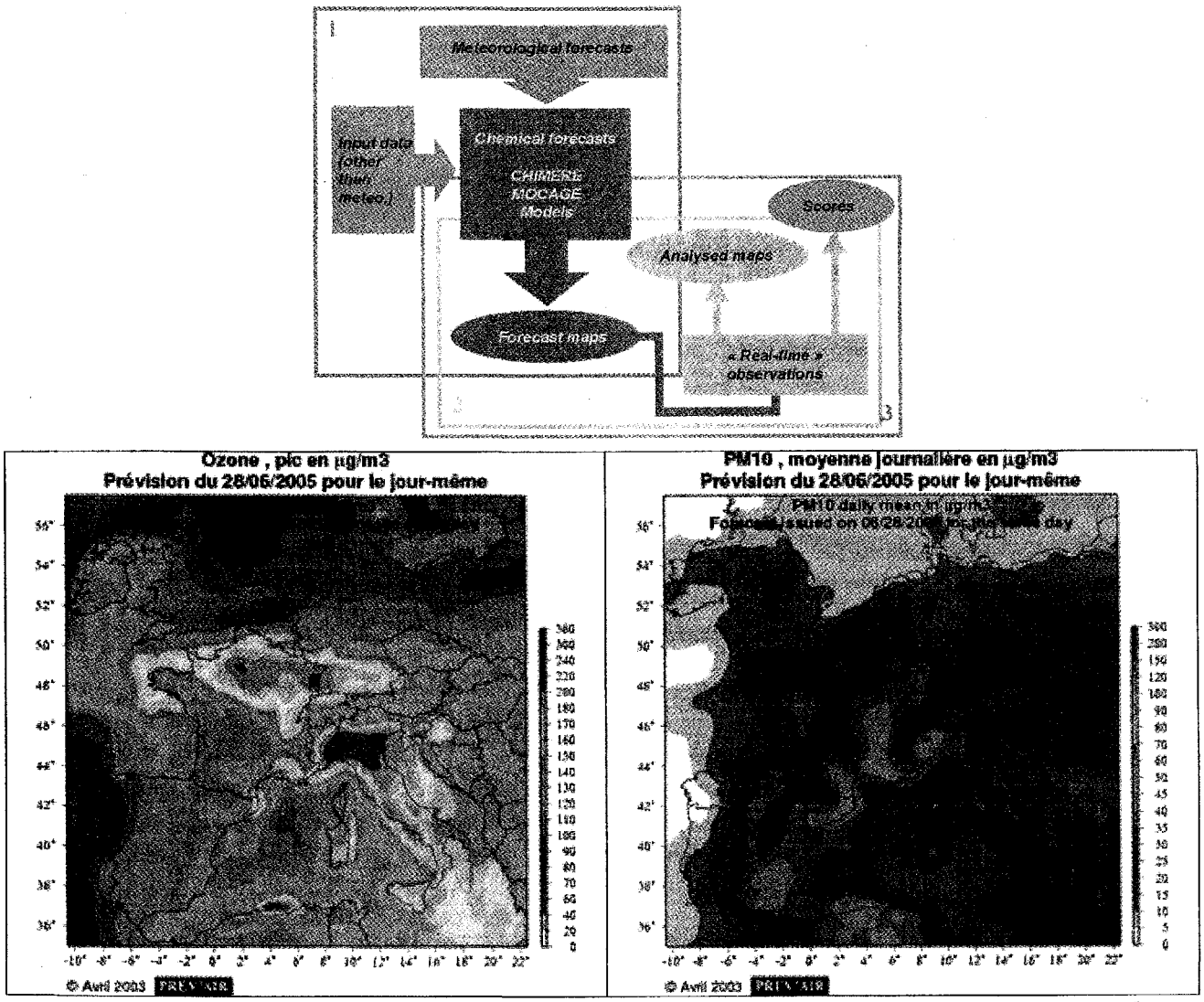

Figure 2 – *Ozone peak and PM_{10} daily mean forecast issued on June 28, 2005 for the same day*

Since the 2003 summer season, the following output data have been made available on a daily basis and can be freely accessed through the Internet:

- Maps of daily maxima and averaged forecast concentrations of ozone and nitrogen dioxide for D-1, D+0, D+1 and D+2 at continental and national scale; maps of daily maxima and averaged forecast concentrations of ozone for D-1, D+0, D+1 and D+2 at global scale.
- Maps of daily maxima and averaged forecast concentrations of particulate matter (PM_{10} and $PM_{2.5}$) for D-1, D+0, D+1 and D+2 at continental scale. Figure 1 displays the ozone peak and PM_{10} daily average forecasts issued on the 08th of August 2003 for the same day (D+0) over Western Europe.
- "Analysed" ozone maps: every morning, ozone peak measurement data coming from the AASQAs are used to readjust the D-1 ozone peak simulation. A kriging-based procedure is applied. At each grid node, the simulated concentration is corrected by a weighted sum of the differences between model and measurement. Twice a day (at the end of the morning and of the afternoon), the D+0 ozone peak forecast is corrected in the same way. Figure 2 displays the

absolute difference (in µg/m3) between the ozone peaks simulated by the CHIMERE model and the analysed peaks.

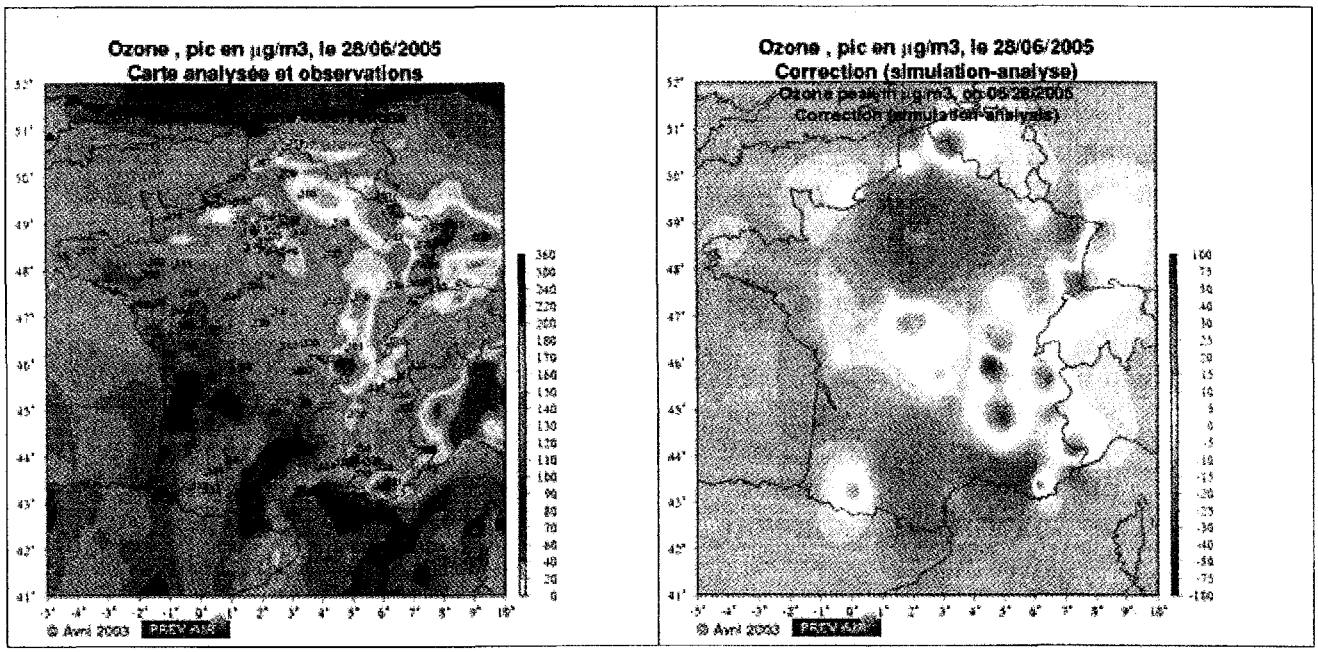

Figure 3 – *Ozone peak analysed map (left) and differences with CHIMERE simulation (right)*

Reliability and scores of the PREV'AIR System

Forecasting mode:

Statistical performance indexes are updated every day and published on the PREV'AIR web site. The availability of the AVN data is of primary importance (the missing data is responsible for 5 % of the forecast failure). Some performance indexes (see table below) have been computed for the last two summers, using the ozone peak concentrations measured in France and calculated for D+0 by the PREV'AIR system. Regarding the ozone peak, the performances of the system are quite satisfying.

		Summer 2003		**Summer 2004**		
Statistical Indexes	Lag	Rural stations	Urban and suburban stations	Rural stations	Suburban stations	Urban stations
Observed mean ozone peak (µg/m3) (nuber of observations used)	D + 0	127.3 (5244)	121.4 (31563)	105.4 (4111)	101.9 (8997)	99.6 (17039)
Simulated mean ozone peak (µg/m3)	D + 0	115.9	115.4	104.5	104.4	104.4
Normalized Bias (%)	D + 0	-8.2	-3.6	-0.8	2.5	4.8
Normalized Mean Square Error (%)	D + 0	19.5	20.6	18.7	17.4	18.9
Correlation	D + 0	0.81	0.80	0.81	0.83	0.84

Analysed maps:

A sensitivity study was conducted to assess the efficiency of the correcting procedure. Two 15-day test periods were selected in the summer 2003 season. 103 ozone monitoring stations, mostly of rural type, were used in the kriging process. 2 rural, 42 suburban and 151 urban monitoring stations were kept for validation. At the end of the tests, different error statistics were calculated. As they indicate, the choice of the kriging parameters is satisfactory and the agreement between model and measurement in rural and suburban areas is significantly improved. For example in cross validation, when averaged over the whole period and the 103 stations, the normalised bias and the root mean square error decrease by 60% and 26% respectively whereas correlation increases by 10%. In validation at the suburban stations, the normalised bias and the root mean square error decrease by 51% and 22% whereas correlation increases by 8%.

USE OF THE PREV'AIR AIR QUALITY FORECASTS AT THE LOCAL SCALE

In relation to the second objective of the PREV'AIR project, numerical air quality forecast data have been put at the disposal of air quality related organisations. The only requirement for the demanding organisations is to fill in a form specifying the exact domain on which the data are to be delivered. Numerical data are then put every morning on the users page of the PREV'AIR web site. Two kinds of data are available over the specified domain: ozone and nitrogen dioxide surface data and 3D data for 22 chemical species. Up to now, about 40 organisations have applied for this service, for various applications: Downscaling and mapping of pollutant concentrations; support to local expert forecasting; provision of boundary conditions to local scale air quality simulation and forecast models. In that context, several initiatives gathering the skills and resources of different AASQA were born in France. In the SYRSO (Regional System for Ozone Monitoring) and OCARINA (Interregional Air Quality Mapping Tool) projects, PREV'AIR forecast maps are reprocessed at a local scale and broadcast on the AASQA websites. In the ESMERALDA and AIRES regional modelling platforms, which involve AASQA respectively from the North and centre part of France and from the Provence-Alpes-Côtes d'Azur region, PREV'AIR numerical outputs are used as boundary conditions for high resolution modelling.

PERSPECTIVES

Different ways of improving the system are being investigated or are planned for the next months:

Ozone forecasting and simulation

- Observation data can be used not only to correct D-1 simulated maps but also to increase the accuracy of forecasts. This is particularly relevant in regions of complex terrain, where the model resolution is not sufficient to reproduce some local pollution patterns.
- According to data availability, the domain considered in the analysed maps could be extended by including observations from surrounding European countries.
- In the framework of the GMES PROMOTE and GEMS European projects, PREV'AIR will quickly evolve in the next few years, including developments both for meteorology and chemistry-transport modeling (CTM). The main goal is to evaluate and improve the model behavior on the vertical dimension. Thereafter, satellite data assimilation will be carry out .
- Finally, the feasibility of using several models to deliver a single forecast (multi model approach) will be investigated, by example coupling CHIMERE and MOCAGE models.

Aerosol forecasting

Aerosol forecasts have been delivered since winter 2003 (starting end of October). The most important improvement expected for aerosols concerns the implementation of a more detailed chemical scheme for secondary organic formation. More observation data will be used in the analysis and verification processes (Italy (ARPA-EMR), Switzerland (NABEL/SAEFL), Poland (Institute of Environmental Protection, Katowice), Germany (UBA)...).