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SAGA: A Decision Support System for Air Pollution Management around a Coal Fired Power Plant

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ABSTRACT

Since the use of meteorological models for weather forecasting, the need for specific meteorological modeling and the complexity of the air pollution dispersion and chemical transformation delayed the use of model-based air pollution forecasting approaches.
From the experience of one of the first source-oriented modeling approach for air pollution forecasting 1994 (Souto et al., 1996; Souto et al., 1998), a new Decision Support System for Air Quality Management, SAGA, was developed to provide support to the power plant staff. SAGA is an operational system for air pollution forecasting and data analysis around air pollution point sources.
SAGA provides 1-day forecasts for the hourly evolution of the most significant meteorological and local air quality parameters; these results are presented in several reports adapted to provide useful information to the power plant staff. Additionally, meteorological and local air quality measurements are available through SAGA, to either confirm or correct the forecast-based decisions.
In this case, the use of meteorological and air quality measurements in real-time is not enough, so the power plant decisions have to be based in the results of meteorological and air quality models, provided by SAGA.

Key Words: Decision Support, Air Quality, Meteorological Forecast

1. INTRODUCTION

As Pontes Power Plant (APPP) is a 1400 MW coal-fired power plant located in Galicia (NW of Spain) that burns a mixing local lignite (with up to 2 % of sulphur) and foreign coal (with less than 0.1 % of sulphur). The combustion gases are emitted through a 350-m stack, in order to prevent local air pollution episodes. However, a complex terrain environment with sea-influence from the Atlantic Ocean can produce meteorological conditions favourable to poor local air quality.
The development of air pollution forecasting systems in APPP, based in source-oriented models, started in 90's. The main goal of these model-based systems was to forecast, 24 hours in advance at least, unfavourable meteorological and SO_2 air quality conditions due to the plume dispersion emitted by the power plant, in order to prevent SO_2 air pollution alerts and to plan changes in the power plant operation (low production, mixing of coals with less sulphur).

The work started in 1990 with the study of the state-of-the-art in meteorological and plume dispersion modeling (Souto et al., 1994), those could be operationally applied to prevent the local air quality around an industrial plant, with limited computational time. First conclusions shown that,

- available operational weather forecasts cannot provide meteorological fields accurate enough in the planetary boundary layer to be coupled to appropriate plume dispersion models, so a local micro-mesoscale meteorological model is necessary,
- some advanced Lagrangian puff models and newer Lagrangian particle models are the most adequate for estimating the local plume dispersion, and
- complexity of the models (specially, the meteorological model) is limited by the available computational time in a workstation environment (less than 1 Mflop).

With these considerations, a plume dispersion forecasting system was developed (Souto et al., 1996; Souto et al., 1998) and started to run in 1994. This system included an emissions module (based in mass balances in the coal-fired plant), a hydrostatic meteorological model coupled to the Spanish National Weather Service forecast, and an operational version of the Adaptive Puff Model (APM, Ludwig et al., 1989) for plume dispersion estimation. Models results could be analysed by using an X-window graphical user interface (GUI), as time-series and maps of meteorological and air quality parameters. The use of this system and the analysis of its results required a good knowledge and experience in both GUI (over UNIX systems) and air quality modeling. Therefore, an expert in these issues provided the recommendations to the power plant staff, in order to prevent future air pollution episodes.

With the increment of the personal computers performance, the possibility of porting this system to a MS-Windows environment was considered. At the same time, the accumulated experience in data analysis for air quality decision support would allow to select the most significant meteorological and air quality data to obtain automatic reports for the power plant staff. With this base, SAGA Decision Support System for Air Quality Management was developed and launched (for testing) in 2003.

In this work a description of SAGA software and its modules are introduced, including the capabilities to adapt SAGA to different environments and numerical models. Following, the use of SAGA at As Pontes Power Plant is considered. Next, some results from the main forecasting parameters provided by the operational SAGA software at APPP are shown. Finally, the main conclusions are presented.

2. SAGA

As a decision support system oriented to air quality management around a point source, SAGA is configured by the combination of three types of models,

a) An emissions model, that estimates the emissions and flow of the flue gas from the point source (typically, an industrial plant), depending on the planned operation, at least one day before.

In APPP, this is based in a coal combustion model, that estimates the flow and composition of flue gas depending on the coals selected and the electric power that is planned to produce tomorrow.

b) A meso-β meteorological model, that provides a high resolution numerical weather forecast, with specific interest in the meteorological parameters with significant effect in the plume dispersion.
At APPP, two meteorological models, ARPS model (Balseiro et al., 2001) and MM5 (Grell et al., 1995), have been tested. Currently, ARPS is the operational model, providing a high resolution numerical weather forecast (24 hours in advance), for the surrounding area 30 km around the power plant. Recently 2-km and 10-km horizontal resolutions were compared (Saavedra et al., 2005) without any significant differences.
c) A Lagrangian atmospheric diffusion model that estimates the local primary pollutants concentrations around the point source. Although secondary pollutants (like O_3) are an significant air quality issue nowadays, the relationships between secondary pollutants levels and local point source emissions are usually more specific to each environment. Therefore, SAGA is currently limited to primary gaseous pollutants.
At APPP, SO_2 emissions dispersion is estimated by using two different Lagrangian diffusion models: Adaptive Puff Model 2 (APM2, Souto et al., 2000) and Lagrangian Particle Model (Souto et al., 2001; Penabad et al., 2002). Both models are currently in testing, so their results are not definitive to the power plant staff.
As the main results, any of each meteorological model can provide one-day forecasts (1-hour and 6-hours average periods) of selected parameters at the point source location: Wind, temperature, lapse rate, solar radiation and cloud cover. In addition, the Lagrangian diffusion models provide one-day ground level concentration forecasts (1-hour average periods) at selected locations around the point source.

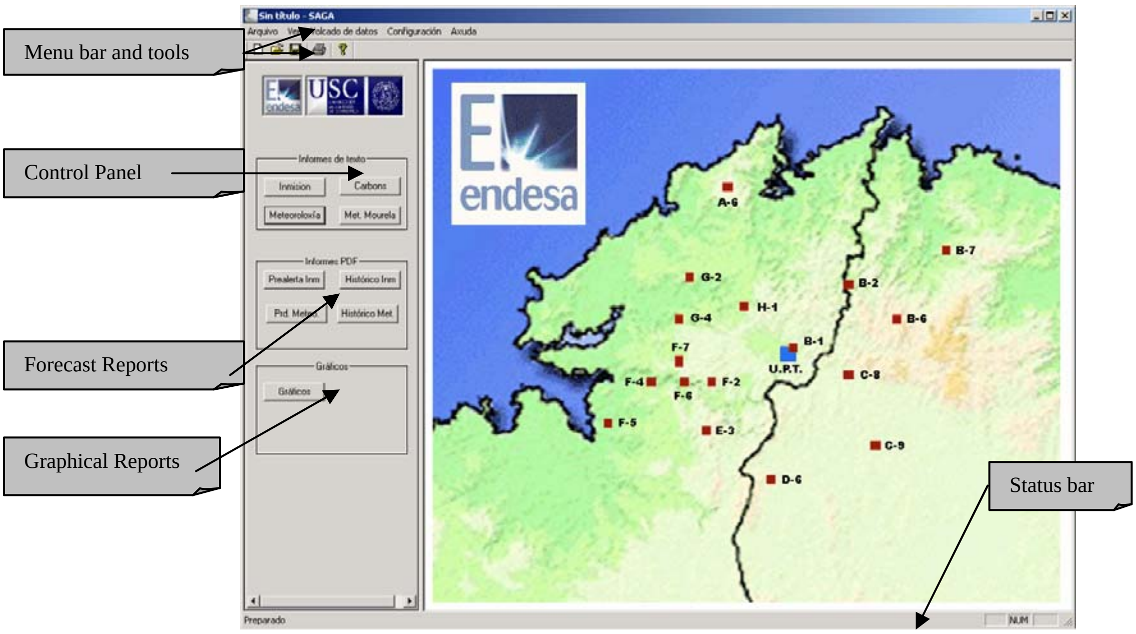

Figure 1. SAGAwin: Main window, including the MS-Windows menu bar, the Control Panel, the Active Window and the Status bar.

2.1. SAGA interfaces

SAGA is a modular software package with two different interfaces,
a) A MS-Windows interface (SAGAwin), that provides general reports about meteorological and air quality measurements and forecasts at the selected point source environment.
b) A Web-based interface (SAGAweb), that provides specific reports adapted to the requirements of the air quality control around the selected point source.
Figure 1 shows the main window of SAGAwin, showing the typical MS-Windows menu bar, a Control Panel to get text or graphical reports, an Active Window (with the APPP environment) for showing the selected reports, and a Status bar for showing any incidence.
As an example of text report, figure 2 shows a ground level concentration (glc) text reports. It can include hourly glc values either measured or forecasted along a selected date.

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Datos Prediccion Meteoroloxica de Inmision

Data: 07/09/2003

Prediccion horaria de concentracion de SO2 en estacions de inmision µg/m3

	A-6	B-1	B-2	B-6	B-7	C-8	C-9	D-6	E-3	F-2	F-4	F-5	F-6	F-7	G-2	G-4	H-1	
00:00	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	ND
01:00	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	ND
02:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	ND
03:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	ND
04:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	ND
05:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	ND
06:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	ND
07:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	ND
08:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	ND
09:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	ND
10:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	ND
11:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	ND
12:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	ND
13:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	ND
14:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	ND
15:00	0	0	0	65	0	0	0	0	0	0	0	0	0	0	0	0	0	ND
16:00	0	0	0	204	0	0	0	0	0	0	0	0	0	0	0	0	0	ND
17:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	ND
18:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	ND
19:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	ND
20:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	ND
21:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	ND
22:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	ND
23:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	ND

Figure 2. SAGAwin: An example of ground level concentration text report, showing some of the forecasted glc hourly values for September, 7th 2003.

Graphical reports combine either meteorological or air quality data, measured and forecasted by SAGA. As an example, on figure 3, SO_2 glc (5-minutes averages) measurements along one day at a specific monitoring station are shown; and, figure 4 includes temperature measurements at 4-levels in the A Mourela meteorological tower, for the same day.

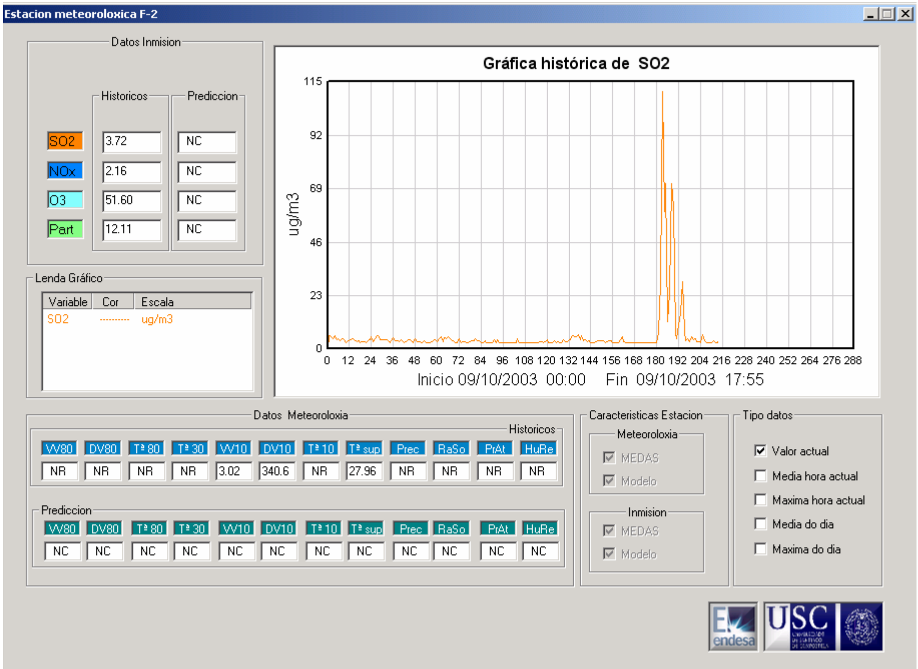

Figure 3. SAGAwin: Measured SO_2 ground level concentration (5-minutes averages), along October, 9th 2003.

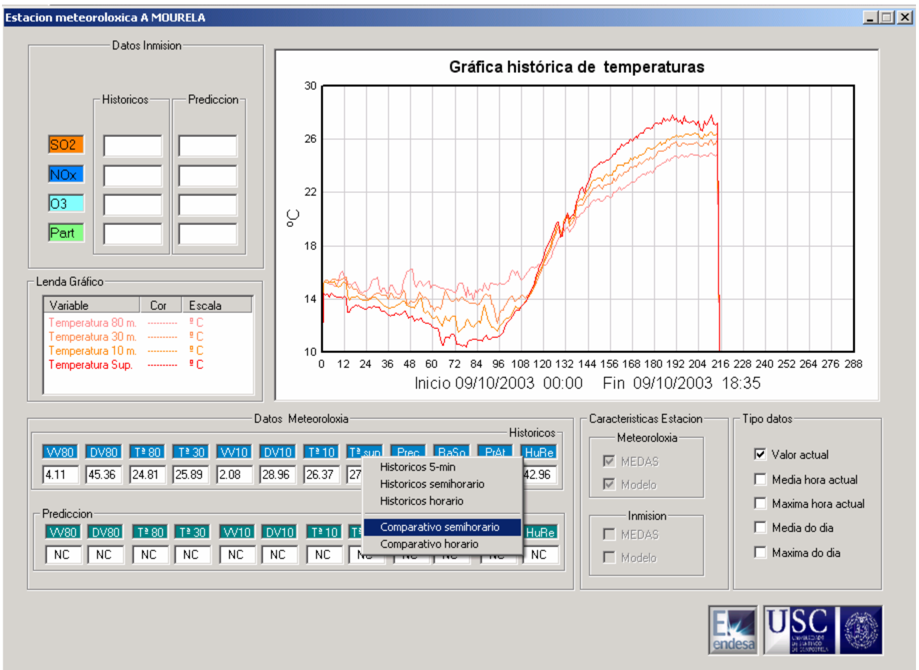

Figure 4. SAGAwin: Measured temperatures (5-minutes averages) at 4-levels (2-m, 10-m, 30-m and 80-m), along October, 9th 2003.

2.2. SAGA reports

Because of the huge amount of information generated by these models (especially, meteorological and dispersion models), specific graphical and text reports were designed to provide the appropriate information to the power plant staff.

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Informe de predicción Meteorolóxica-Data:23/09/03
(Elaborado o 22/09/03 ás 07:14:31)

	Madrugada 00:00-06:00 horas	Mañá 06:00-12:00 horas	Tarde 12:00-18:00 horas	Noite 18:00-24:00 horas
Dirección vento 80m	N	NE	NE	NE
Velocidade vento 80m (m/s)	(5,7]	(5,7]	(9,13]	(13,...)
Temperatura sup. (ºC)	14.0/12.0	11.0/12.5	14.3/16.2	15.4/12.1
Nubosidade(%)	74	52	17	8
Radiación solar(W/m2)	0/0	0/414	694/495	341/0
T80-30(ºC)	-0.10/0.70	0.60/-1.00	-1.00/-0.60	-0.50/0.20
Observacións	Predicción elaborada para o entorno da estación meteorolóxica de A Mourela			

Dirección vento 80m.: moda 6h.
Velocidade vento: media 6h. en intervalos [0,1],(1,3],(3,5],(5,7],(7,9],(9,13] (13,...)
Temperatura superficie: mín. e máx. horaria en orde cronolóxico
Nubosidade: media 6h.
Radiación solar: mín. e máx. horaria en orde cronolóxico
T80-30: mín. e máx. horaria en orde cronolóxico

(a) Meteorological Forecast (MF)

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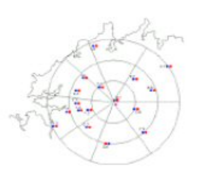
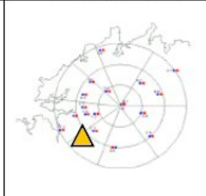
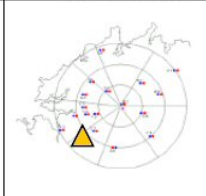
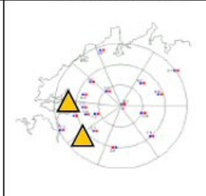
Informe de prealerta de Inmisión-Data:23/09/03
(Elaborado o 22/09/03 ás 07:14:31)

	Madrugada 00:00-06:00 horas	Mañá 06:00-12:00 horas	Tarde 12:00-18:00 horas	Noite 18:00-24:00 horas
Zona				
Duración		Media	Media	Alta
Intensidade		Media	Media	Media
Dirección vento 80m	N	NE	NE	NE
Velocidade vento 80m (m/s)	(5,7]	(5,7]	(9,13]	(13,...)
Temperatura sup. (ºC)	14.0/12.0	11.0/12.5	14.3/16.2	15.4/12.1
Nubosidade(%)	74	52	17	8
Radiación solar(W/m2)	0/0	0/414	694/495	341/0
T80-30(ºC)	-0.10/0.70	0.60/-1.00	-1.00/-0.60	-0.50/0.20
Observacións				

Dirección vento 80m.: moda 6h.
Velocidade vento: media 6h. en intervalos [0,1],(1,3],(3,5],(5,7],(7,9],(9,13] (13,...)
Temperatura superficie: mín. e máx. horaria en orde cronolóxico
Nubosidade: media 6h.
Radiación solar: mín. e máx. horaria en orde cronolóxico
T80-30: mín. e máx. horaria en orde cronolóxico

	Baixa	Media	Alta
INTENSIDADE:	△	▲	▲
DURACIÓN:	< 1 hr.	1-2 hr.	>= 2 hr.

(b) Meteorological and Air Quality Forecast (MAQF)

Figure 5. (a) MF and (b) MAQF reports provided by SAGA to the APPP staff.

Two main reports were designed to answer to the power plant staff requirements (figure 5),

a) A Meteorological Forecast (MF) report, with meteorological parameters that are significant to local air quality.
b) Meteorological and Air Quality Forecast (MAQF) report, with the same meteorological parameters plus some information about location, duration and intensity of ground level concentration episodes forecasted by SAGA, around the power plant.

Although the MAQF seems to be more useful, because it includes direct information of the impact in the local air quality, the uncertainties in the estimation of the local pollutants dispersion show that meteorological parameters are a better guide for the power plant staff. In fact, before the availability of a specific MF report, they used to analyze the meteorological measurements in order to consider their influence in the air quality in the same day; therefore, with the MF report they can apply their experience directly to a qualitative estimation of the air quality, for the next day.

Figure 6. SAGAweb main page, showing the MF report at A Mourela location for June 21st, 2005 (obtained on June 20th, 2005). MF reports for June 20th and June 22nd are available too, at six different locations.

Both reports, MF and MAQF, are available by using the SAGAwin interface. However, because of the usefulness of the MF report, only this last one was included in the SAGAweb. In addition, SAGAweb (figure 6) provides MF reports for six different locations around the power plant (at different meteorological stations), with a 3-days forecast (today, tomorrow and the day after tomorrow), and access to old MF reports (historical data).

3. RESULTS

SAGA system is being applied currently by the APPP is a coal-fired power plant that burns a mixing local lignite (with up to 2 % of sulphur) and foreign coal (with less than 0.1 % of sulphur). The combustion gases are emitted through a 350-m stack, in order to prevent local air pollution episodes.

Every day, the power plant need to evaluate to convenience of changing the coal mixing for the next day, taking into account the risk of local poor air quality (due to SO_2 ground level concentration levels). This risk is evaluated by the power plant staff considering the meteorological parameters included in the MF report, as follows,

Wind speed: Low winds are favourable for mixing a high level emission, as the As Pontes power plant emissions. Therefore, winds above 9 m/s are usually required for causing poor local air quality.

Wind direction: Southwest and Northeast sectors around the power plant are usually more affected by the SO_2 plume, because of their complex topography.

Temperature: High surface temperatures (respect to aloft temperatures) are usually favourable to create convective plumes, with higher risk of plume down.

Cloudiness and solar radiation: High solar radiation and clear sky are more favourable to create convective plumes, with the same result.

Surface lapse rate: Lapse rate from 80-m to 30-m is a direct magnitude of the atmospheric stability near surface; as this parameter is measured and considered in the past by the power plant staff, they can be used it to identify the risk of poor air quality.

Aloft lapse rate: Lapse rate from 800-m to 500-m is a direct magnitude of the atmospheric stability around the plume transport layer. Jointly to the surface lapse rate, it can help to consider the influence of thermal inversion in the plume dispersion and the local air quality.

A new MF report is available before 9am. Power plant staff analyzes it and, before the end of the morning, they consider some possible changes in the coal mixing ratio to be applied to the next day. Usually, they keep a 70:30 (lignite:foreign coal) mixing ratio, but the power plant is prepared to change to 100 % of foreign coal, if it is necessary. However, this severe change cannot be applied quickly, in order to prevent fails in the combustion systems; therefore, mixing ratio should be changed several hours before the meteorological conditions for poor local air quality are expected.

4. CONCLUSIONS

The development and application of a decision support system for air quality management around a point source is presented. The system, namely SAGA, provides meteorological and air quality forecasts 1-day before to a 1400 MW coal-fired power plant staff, in order to help in the planning of the plant operation. Currently, a meteorological forecast (MF) report specifically adapted to this point

source requirements in the most useful result provided by SAGA. The meteorological parameters included in this report (related to the local plume transport and dispersion) are daily analysed by the power plant staff to decide the changing of the coal mixing for the next day. This coal mixing can be programmed to reduce the SO_2 emissions during short periods, in order to prevent local air pollution episodes.
SAGA is nowaday focused in primary pollutants (like SO_2), but it is planned to include other pollutants (as NO_x and O_3), by changing the air quality models applied. CAMx, STEM-II and, more recently, WRF-CHEM, are possible candidates to be applied in SAGA.

5. ACKNOWLEDGEMENTS

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