REAL TIME, HIGH RESOLUTION REGIONAL WEATHER AND AIR QUALITY FORECASTING SYSTEM IN WEST MACEDONIA, GREECE

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ABSTRACT
This paper presents an overview of the UoWM operational model for predicting the prevailing meteorological and air quality conditions on a high resolution (2 x 2 Km^2) scale. The MM5 – SMOKE – CMAQ has been suitably parameterized with respect to the particular geographical and climatic characteristics of Region of West Macedonia. The system is designed to produce hourly forecasts for a 72 hours horizon in addition to air quality indices and comparisons to the current EC and national regulatory limits. The performance of the system against observational data is discussed.

INTRODUCTION
The greater lignite basin of Bitola – Florina – Ptolemais – Kozani is the major power supplier for Greece and the neighboring FYROM. The Ptolemais Amydeon lignite basin has been exploited by PPC (Greece) for the last 40 years. Eighteen lignite-fired power units of a total capacity of 4,013 MW supply Greece with electric energy (65% of the total electric energy consumption). The annual lignite consumption is over 70 million tonnes. The Pelagonian basin, situated near Bitola is the major Lignite Center for FYROM. The annual production of lignite is approximately 7 million tonnes feeding three power stations of equal capacity (3 x 225 = 675 MW). The lignite extracted represents the 82% of the total coal used for power generation in FYROM. Bitola thermal power plants cover 70% of the countries energy needs.

For areas located in the Kozani-Ptolemaïda basin PM10 concentrations seem to be the most serious problem (Triantafyllou 2003), as the measured ambient concentrations of suspended particles are at high levels and under certain meteorological conditions exceed local and international standards. The epidemiological study of Papadakis et al. (2003) has shown that the crude mortality, infant mortality, as well as the specific by cause mortality in Kozani County is not basically different from that of the general Greek population. However, pollution was found to have a harmful effect on the respiratory system of children, mainly attributable to the occurrence of rhinitis and infectious bronchitis (Sichletidis, 2005)

To assess current and future air quality conditions, UoWM is developing and applied a decision support system suitably parameterized for the region of Western Macedonia, Greece. It could be potentially employed different stakeholders or end-users (such as policy-makers, local authorities, Greek Public Power Corp.) to conduct screening studies and/or detailed modelling assessments of the effects of pollution in the regional environment. The modelling system is based on a detailed emission inventory for the region (Vlachogiannis et al, 2007) that currently undergoes extensive verification / validation and an air quality monitoring station located in the premises of UoWM, at the city with the highest population of the region. For the purposes of this study, a number of different meteorological scenarios (weather types) representing the prevailing weather conditions are examined and presented.

DESCRIPTION OF THE WORKING DOMAIN AND MAIN POLLUTION SOURCES

The working domain covers the four prefects of Western Macedonia (Kozani, Kastoria, Grevena and Florina) with a total area of approximately 9500 km^2. The working domain was split into 72 * 72 cells of 4 km^2 each. The region is a predominantly mountainous and sparsely populated area of nearly 300,000 inhabitants.

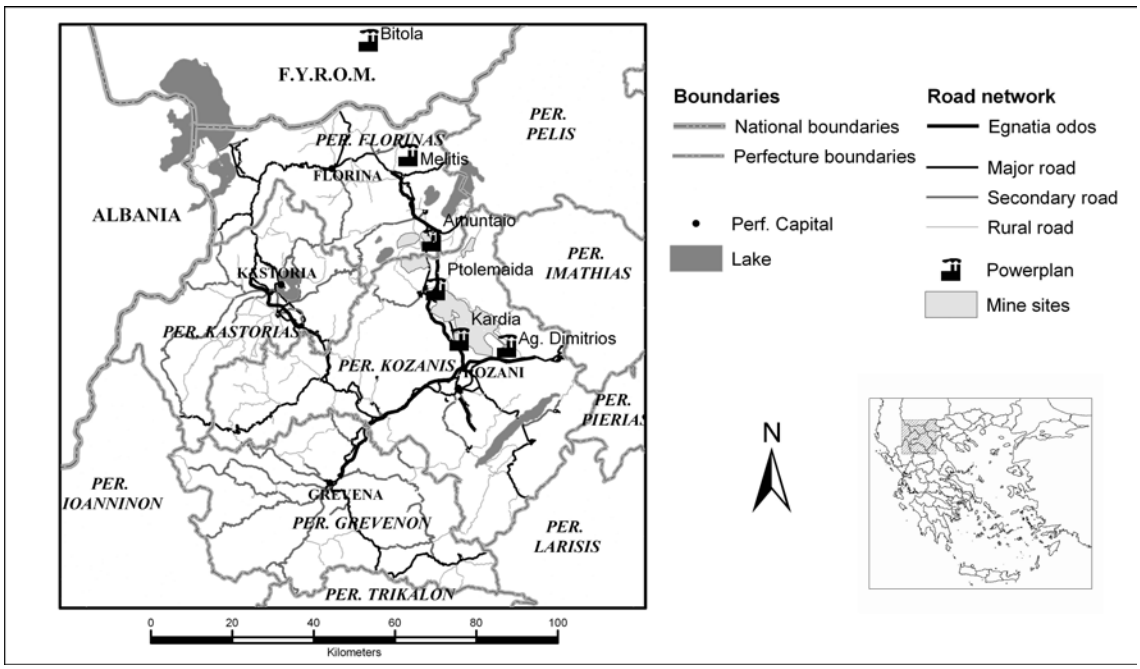

Fig 1; Map of Western Macedonia

The Greek Public Power Corporation (PPC) operates 5 thermal power plants in the area (Table 1). Furthermore, approximately 20 km from the border between FYROM and Greece, the Bitola thermal power station operates. The station significantly influences the atmospheric quality of the northern cities of West Macedonia in the event of north winds.

Table 2. Yearly emissions from the thermal power plants. (EPER)

EGU	Capacity	Energy	SO_2	NO_x	PM10	CO
	MW	MWh	tn / year	tn / year	tn / year	tn / year
AG. DIMITRIOS	1595	11481875	6950	21600	19900	5540
KARDIA	1250	9107935	11700	19900	4560	2290
PTOLEMAIDA	620	3784147	14000	7640	4050	2820
AMYNTAIO	600	3853170	35800	7500	1830	5060
MELITI	330	2218250	3010	1990	238	-
BITOLA	675	4340000	64000	6200	1920	803

SCENARIO IDENTIFICATION

A number of different weather types have been identified using a methodology based on the subtractive clustering algorithm coupled with the “compactness and separation criterion” for identifying the optimal number of clusters (Sfetsos et al, 2005). Global GFS data for the entire

2006 (u and v wind components at 10m agl, Temperature at 2m agl and the mixing layer height; MLH) at three periods of the day are used (00:00, 12:00, 24:00). The analysis identified three different days that contain the prevailing weather types:

1. *Day1; 2nd January 2006*, South – Southwest winds dominate the morning period which swifts into a westerly one during the late afternoon hours. The day has high precipitation, relative humidity in the order of 98-100% and MLH approximately 500 m during all hours
2. *Day2; 22nd January 2006*, North winds dominate the region, which due to topography create a channelling effect. During the afternoon hours, the cloud coverage increases which stabilizes the MLH variability into approximately 400 m. The temperature is below zero for all hours of the day, which is a characteristic of the days with northerly winds.
3. *Day3; 12th December 2006,* Stationary conditions are observed. The lowest part of the atmosphere is dominated by weak south winds, which turn into north during late afternoon and evening hours. The MLH exhibits a diurnal variation which peaks into 1000 m. The majority of the day is clear with scattered clouds appearing into the late evening hours.

DEVELOPMENT OF MODELLING SYSTEM

The MM5 version 3.7.2 (e.g. Dudhia 2004; Grell et al. 1994) has been suitably parameterized for producing the meteorological prediction in the working domain. It is a well tested model and applied by numerous institutions in operational applications. For the Western Macedonia environmental management system the following options were used:

- Topography data from USGS
- The initial data were obtained from the GFS models located in the daily global repository of the National Center for Environmental Prediction, USA.
- 4 domains of dimensions 39x39, 36x36, 54x54, 72x72 and respective spatial resolutions 54 km, 18 km 6 km and 2 km were finally selected, using two-way nested scheme runs on (D1 and D2 together) and (D3 and D4 together).
- 23 vertical layers were selected
- The MRF PBL scheme was applied on all four selected domains.
- Grell cumulus parameterization on the domains D1-D3.
- Simple ice as the explicit moisture scheme.
- CCM2 radiation scheme.

The emissions processing was performed using the SMOKE modeling tool. It was used to prepare gridded, hourly temporalized and speciated emissions for use in the CMAQ. The VOC and PM-10 emission data were speciated to 11 CB-IV chemical species and 8 particulate species. SMOKE was run independently on each one of the selected cases in to account for the influence of the different meteorological conditions. The emissions from the power plants stacks were assigned into different model layers based on Brigs plume rising algorithm.

The applied chemistry/transport model was CMAQ version 4.4 (Byun et al. 1999). This model uses the outputs from the meteorological model and the emission processor to simulate pollutant transport processes and chemical transformations in the atmosphere.

- The horizontal working domain was the one produced for MM5.
- 16 vertical layers were used, with reduced resolution on the upper part of the domain.
- The CB-IV chemical mechanism was selected.
- For the purposes of this study the initial and the boundary conditions were kept constant for all examined cases.

For post-processing, a customised interface build on MATLAB processing the output of all models has been developed and applied. For air quality predictions, it is also possible to provide comparison with existing legislative requirements. In the following contour plots, + symbolises the location of a power plant and a □ the main cities of the region.

DAY1

The plume from power plants on the Greek side of the borders effect the air quality in the Bitola area (near the top cross) in the presence of medium to strong south winds. The daily PM10 plot shows increased levels in the Ptolemais Amyndeon basin.

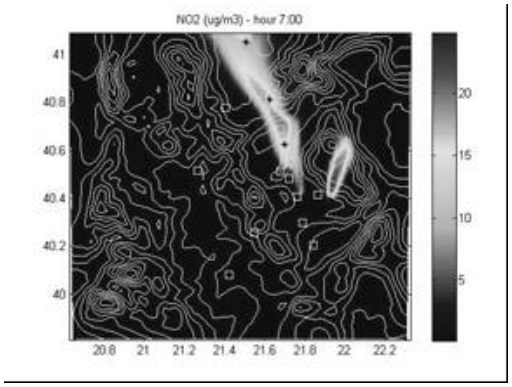

Fig. 2; NO_2 snapshot

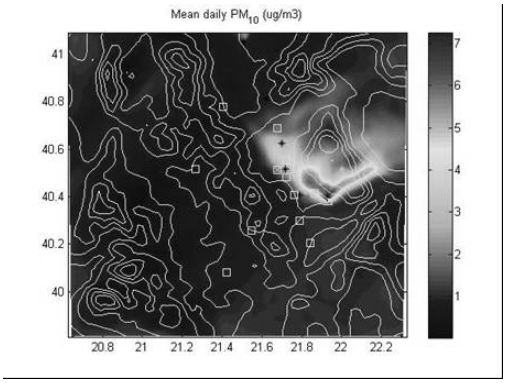

Fig. 3; Mean daily PM_{10}

DAY2

On a day of strong north winds, plume from the REK Bitola power plant significantly effect the air quality of the entire Western Macedonia region, which wield a cumulative effect with the emissions from PPC power plants. The daily PM10 plot shows increased levels in the southern part of the working domain.

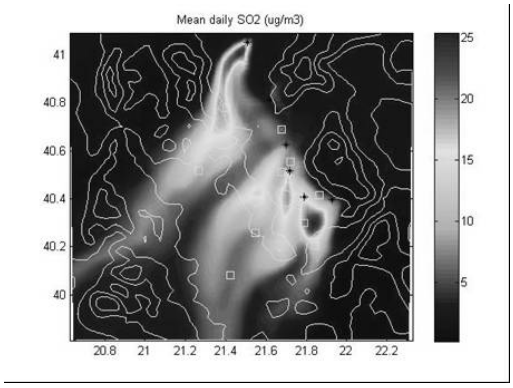

Fig. 4; Mean daily SO_2

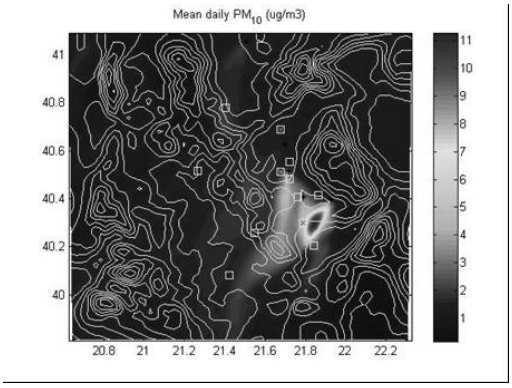

Fig. 5; Mean daily PM_{10}

DAY3

This weather pattern appears to produce the worse air pollution effect in the region of Western Macedonia. The mean daily SO2 value is higher on the north part of the lignite producing basin with local hot spots near the power plants. The PM10 values exceed legal limits in the vicinity of the Ag. Dimitrios power plant, which according to EPER data, is the source with the highest emission levels.

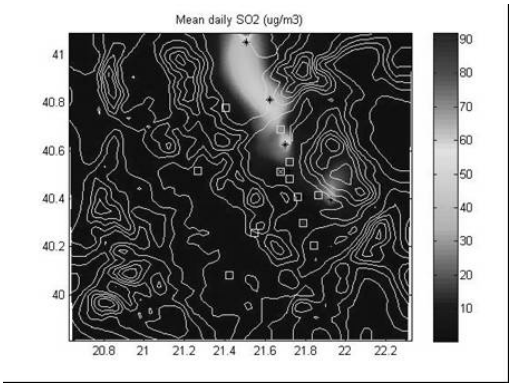

Fig. 6; Mean daily SO_2

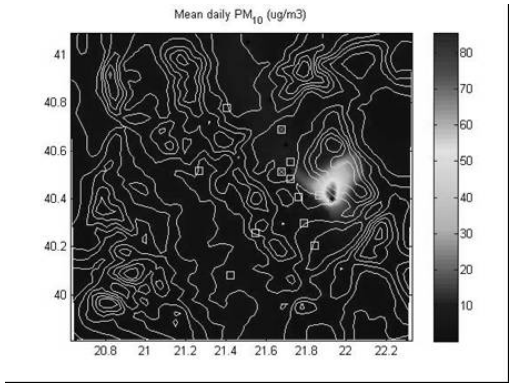

Fig. 7; Mean daily PM_{10}

CONCLUSIONS

This paper provided an overview of the early modelling activities of the University of Western Macedonia with respect to the computational part of an integrated environmental management system. The MM5-SMOKE-CMAQ combo has been applied on three selected cases that represent the predominant weather types of the region.

From the present analysis two main conclusions can be drawn: the significant impact of transboundary pollution and that stationary conditions are those that significantly effect the air quality of the area.

ACKNOWLEDGEMENTS

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