Short term health impact of air pollution in Europe

R. San José [a], J.L. Pérez [a] and R.M. González [b]

[a] *Environmental Software and Modelling Group, Computer Science School, Technical University of Madrid (UPM), Campus de Montegancedo, Boadilla del Monte, 28660 Madrid (Spain).*
[b] *Department of Geophysics and Meteorology, Faculty of Physics, Complutense University of Madrid (UCM), Ciudad Universitaria, 28040 Madrid (Spain)*
Email: Roberto@fi.upm.es

Abstract: Air pollution has a substantial impact on human health. During the last decade, a substantial improvement on air quality modelling has been performed. The last decade scientific studies have indicated an association between air pollution to which people are exposed and wide range of adverse health outcomes. Sophisticated 3D Eulerian numerical models have been developed to be applied to estimate the air pollution concentrations based on the improvement on weather forecasts and the substantial progress on knowledge on atmospheric chemistry. The accuracy on the estimated concentrations at surface level on space and time is currently quite important. We have developed a tool that is based on a model (MM5-CMAQ) (PSU/NCAR and US EPA) running over Europe with 50 km spatial resolution, based on EMEP (European official emission inventory) annual emissions, to produce a short-term forecast of the impact on health.

The system is based on the BENMAP tool developed by EPA (US). The system estimates the mortality change based on the air pollution change, the mortality effect (Beta), the mortality incidence and the exposed population. In order to estimate the mortality change (forecasted for the next 24 hours) we have chosen a log-linear (Poisson) regression form to estimate the concentration-response function. The parameters involved in the C-R function have been estimated based on epidemiological studies, which have been published by the European APHEIS (Air Pollution and Health: A European Information System) program and the WHO (World Health Organization). We have derived the relationship between concentration change and mortality change from the C-R function which is the final health impact function. Since with a 24-hours air pollution forecast of the air concentrations, we have used the European epidemiological studies with different relative risks (RR) to relate them with the daily air forecasted concentrations to obtain a relationship to be applied to all grid cells in the European domain. Since the relationship depends on the forecasted air concentrations, this relationship is calculated daily. In this contribution we show health impact European maps for PM10 daily average and O3 (maximum of the 8-hour moving average) and deaths for all causes, deaths for respiratory and cardiovascular diseases and Hospital admissions for respiratory and cardiovascular diseases. All this calculations are made using a computational scripts developed ad-hoc for the operational system.

Keywords: *Health impact, air pollution, numerical model, relative risk*

1. INTRODUCTION

The important air pollution episodes in Europe and North America before 1960 provided indisputable evidence that those high levels of air pollution can have very important adverse health effects, including a significant increase in mortality. Air pollution causes a variety of health problems for people of all ages. . Human exposure to air pollution may result in a variety of health effects, depending on the types of pollutants, the magnitude, duration and frequency of exposure and the associated toxicity of the pollutants of concern. A variety of air pollutants have known or suspected harmful effects on human health and the environment. Some of the most harmful pollutants are particulate matter (PM), oxides of nitrogen, sulphur dioxide, carbon dioxide, ground level ozone and ammonia (WHO, 2003). In most areas of Europe, these pollutants are principally the products of combustion from space heating, power generation or from motor vehicle traffic. Recent studies investigating the adverse health effects of air pollution indicate that effects exist around and below the current national and international air quality guidelines and standards. Much of the population lives in areas where the concentration of air pollution reaches levels that affect health (WHO, 1995). Air pollution has direct and indirect costs on the economy. Prescription charges and healthcare services are direct costs, whereas lower productivity resulting from absenteeism is an indirect cost. Moreover, reduction in life expectancy resulting from air pollution is a loss in human capital

Exposure to pollutants has been associated with increases in mortality and hospital admissions due to respiratory and cardiovascular problems. These effects have been found in short term studies, which are focused on daily variations in air pollution and health. In case of European cities, urban air quality represents a major public health problem. Different pollutants may have widely different concentration-response characteristics. The health endpoints associated with exposure to individual air pollutants may include the exacerbation of respiratory symptoms and cardiovascular disease, increased hospital admissions, compromised immune systems, premature death, cancer or impairment of neurological development (WHO, 2000a). The short-term adverse health response may lag the exposure by several hours, up to period of several days (Lipfert, 1994). Individual susceptibility and the prevalence of health conditions that predispose the exposed population to an adverse response further complicate attempts to accurately estimate the actual site-specific health risk with air pollution (WHO 2000b). Information of the relationship between exposure and response is necessary to estimate the potential health risks.

Epidemiological studies determine relationships between air pollution and health effects in populations, they are called concentration-response functions. These functions empirically explain variations in the number of cases of illness or death observed in a population based on changes in the ambient concentrations of the air pollution. Air pollution is a major environmental risk to health. By reducing air pollution levels, we can help countries reduce the global burden of disease from respiratory infections, heart disease, and lung cancer. Health impact assessments play a very important role in the field of air pollution.

2. TOOL DESCRIPTION

The tool can be used to forecast the short term health impact of air quality, PM10 and O3, over Europe on the health outcomes: total premature mortality, excluding accidents and violent deaths, cardiovascular mortality and respiratory mortality. The evaluation of health risk requires the assessment of the actual concentration levels in the air over time (today and tomorrow). Air pollution are forecasted from the modelling system (MM5-CMAQ) running over Europe with 50 km spatial resolution, based on EMEP annual emissions. The health effects forecasted are: mortality for all causes, mortality for respiratory causes and mortality for cardiovascular causes for PM10 daily average and Ozone maximum daily 8 hours mean. The final product is the forecast of the European mortality change (%) for tomorrow related today´s mortality due to air pollution concentration changes.

The relationship between concentration and health effect is modelled with a Log-Linear regression (Poisson) as a concentration-response (C-R) function. Then it is derived the relationship between concentration change and mortality change from the C-R function and this is the final health impact function (1)

$$\Delta y = y_0 (e^{\beta \Delta C} - 1) \tag{1}$$

Where y_0 is the baseline incidence rate of the health effect, β is the mortality effect estimation, ΔC is the difference between tomorrow and today air pollution concentration. Our system forecast percentage (%) change of the health effect, so it is independent from the population and the incidence rate. The epidemiological studies do not report the β parameter of the C-R function, they report the relative risk (RR) associated with a given change in the pollutant concentration, but β and RR are related following the equation (2).

$$\beta = \frac{Ln(RR)}{\Delta c} \quad (2)$$

The system use the RR values published on the "Meta-Analysis Of Time-Series Studies And Panel Studies Of Particulate Matter (Pm) And Ozone (O3)" by H. Ross Anderson, Richard W. Atkinson, Janet L. Peacock, Louise Marston and Kostas Konstantinou. It is part of the WHO project "Systematic review of health aspects of air pollution in Europe", which is funded by the European Commission and is intended to provide input to the Clean Air For Europe (CAFE) programme. In this case there is no reference values of concentration for each RR, so concentrations are taken from the operation air pollution modelling system on the cities which have RR values. Also Spanish epidemiological studies are used to get more RR values. These published on the EMECAM PROJECT: Spanish Multicenter Study on the Relationship Between Air pollution and the Mortality.

Figure 1 show RRs from Spanish cities and theirs PM10 daily average concentrations. Figure 2 and 3 show the RR values used for different European cities included in the system.

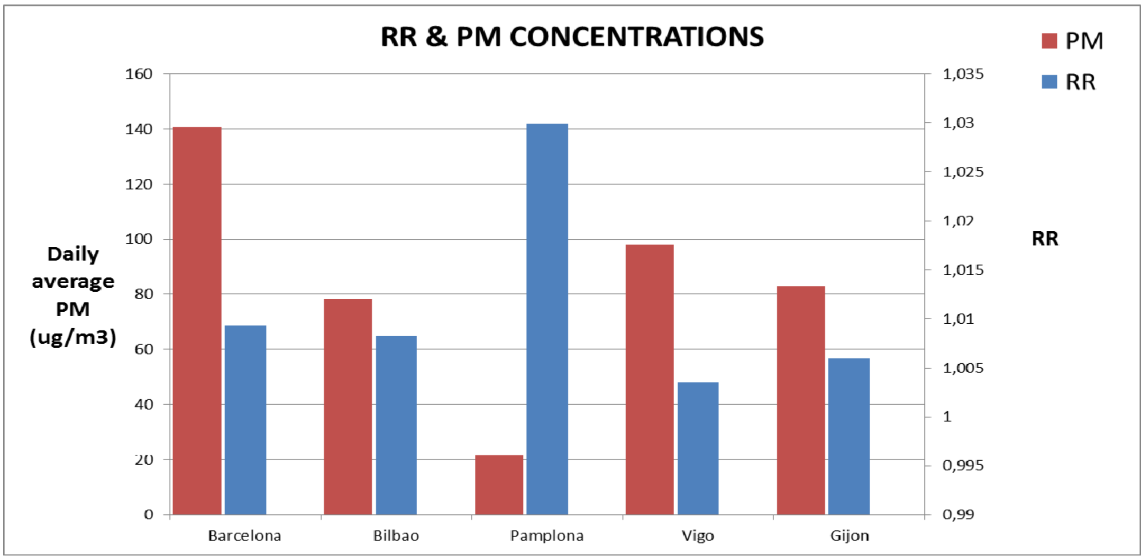


Figure 1. RR and PM10 daily average for all causes mortality

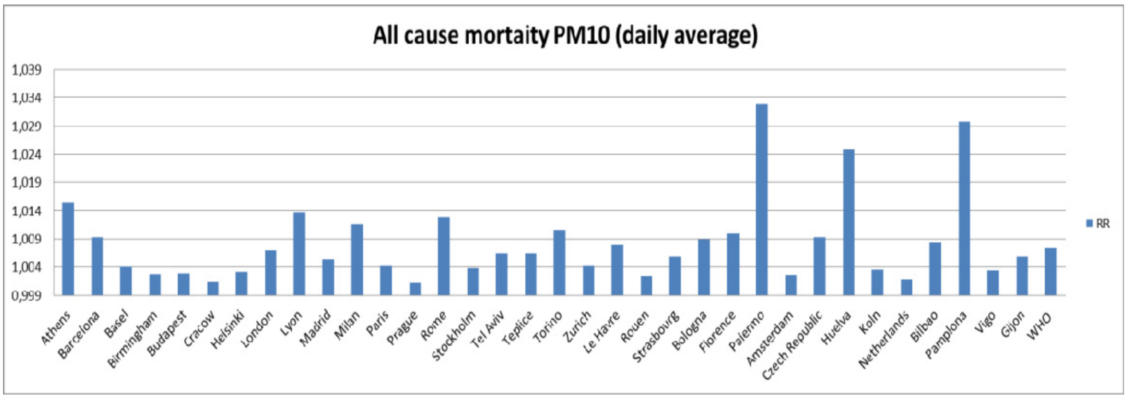


Figure 2. RR for all causes mortality for the PM10 daily average

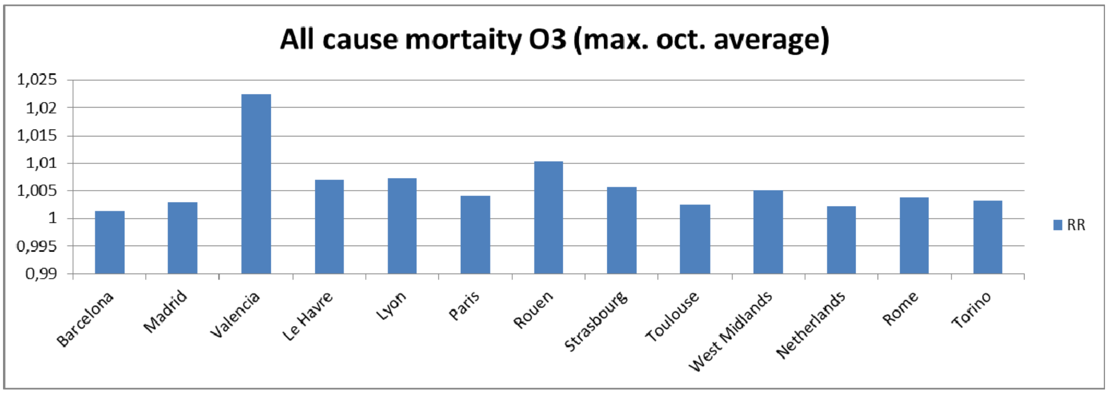


Figure 3. RR for all causes mortality for the O3 maximum octoh. average

The air pollution concentrations are taken from the air quality real-time operational forecasting system which covers all Europe by using the MM5–CMAQ–EMIMO air quality modelling system. Figure 4 shows a scheme of the system.

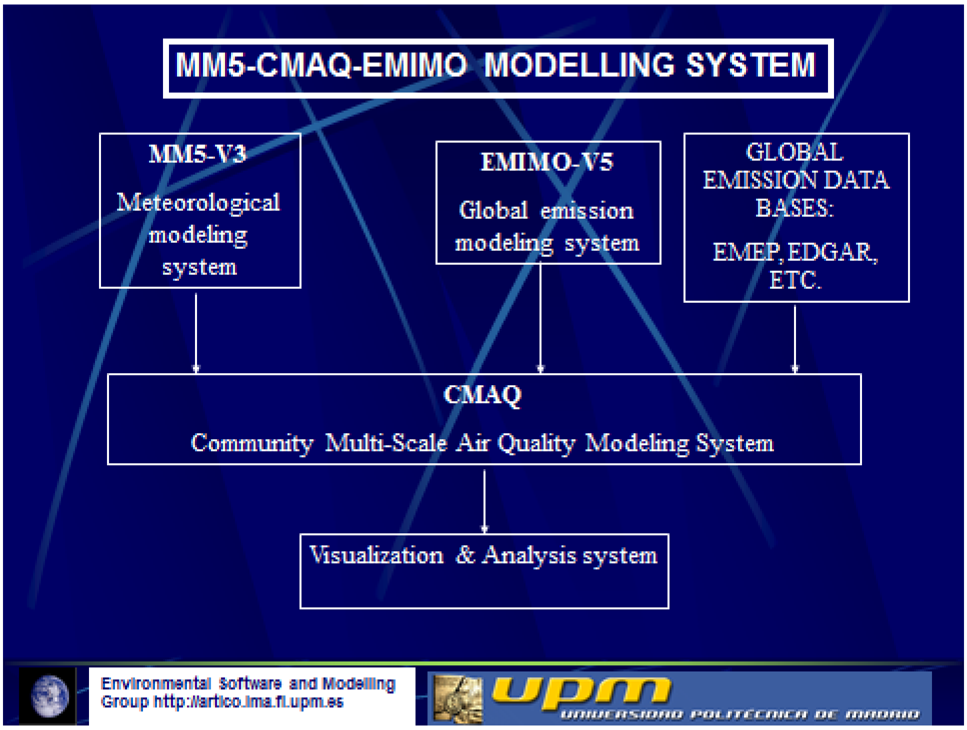


Figure 4: Air quality forecasting system MM5-CMAQ-UPM

It uses the MM5 meteorological mesoscale model developed by Pennsylvania State University (USA) and NCAR (National Centre for Atmospheric Research, USA) (Grell et al., 1994). The CMAQ model is the Community Multiscale Air Quality Modelling System developed by EPA (USA) (Byum et al. 1998) and EMIMO is the Emission Model developed by San José R. et al. (2003) (San José et al, 1997). MM5 is a well-recognized non-hydrostatic mesoscale meteorological models which uses global meteorological data produced by global models such as GFS model (NCEP, USA) to produce high resolution detailed three dimensional fields of wind, temperature and humidity which are used in our case as input for the photochemical dispersion model CMAQ (San José et al., 1998). In addition of MM5 output data, EMIMO model produces for the specific required spatial resolution, hourly emission data for different inorganic pollutants such as particulate matter, sulphur dioxide, nitrogen oxides, carbon monoxide and total volatile organic compounds VOC's. The VOC's are splitted according to SMOKE (Sparse Matrix Operator Kernel Emissions (Williams et al., 2001) and (Flassak et al., 1987). In this particular case, the EMIMO model is applied by using the annual EMEP official emissions from 2003 for the whole of Europe. The full system is called OPANA V3 since the V2 included adaptations of the MEMO model (REMEST) and on-line implementation of the SMVGEAR (Sparse Matrix Vector Gear Technique) implicit technique with the CBM-IV chemical carbon bond mechanism.

The system has been evaluated by comparing the modelling results and the observed results in different air quality monitoring stations in Madrid area. In Figure 5 we show time series comparison between observed and modelled data during 2005 year. Black lines are modelling data and red line is observed data from monitoring stations. In general agreement is quite good.

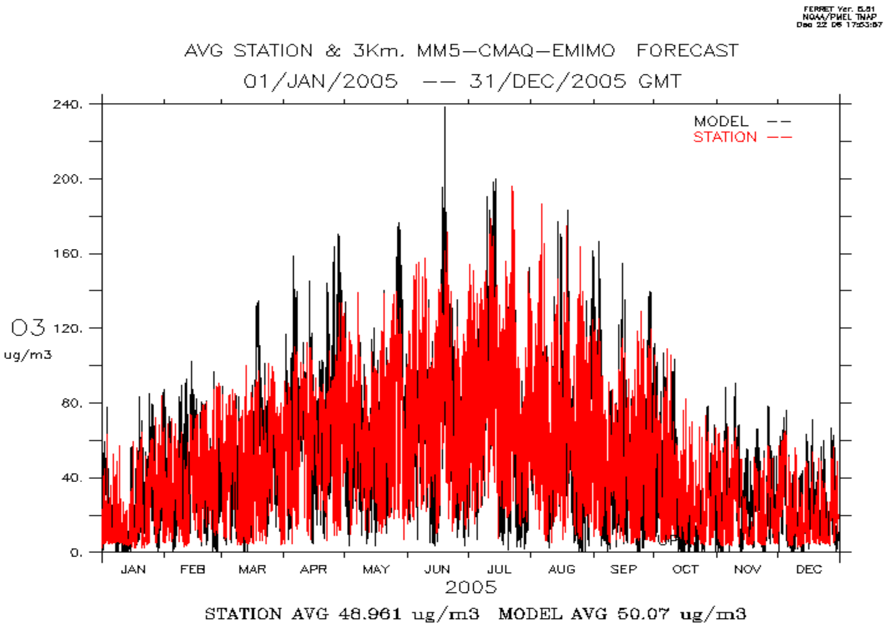


Figure 5. Time series comparison between observed and MM5-CMAQ data during

By each grid cell and health indicator, the system searches the city with the air pollution levels close to the level of the grid cell and it chooses the RR associated to the selected city. Calculate the concentration change between tomorrow and today and finally forecast the mortality change for tomorrow using the log-linear C-R function.

3. RESULTS AND CONCLUSIONS

Figure 6 shows an example of forecast daily mortality change (%) by Ozone for tomorrow, April, 12, 2013 related to today. It is mortality for cardiology with Ozone 8 hour’s average as air quality indicator. We can see increases up to 10 % over Mediterranean area. Figure 7 shows forecast of daily mortality change (%) by particles for tomorrow, April 12, 2013 related to today. It is mortality for all causes with PM 24 hours average as air quality indicator.

We have developed an operational health impact system based on the MM5-CMAQ operational air quality forecasts over all Europe with 50 km spatial resolution. The tool can be used to assess the impact of atmospheric pollution on human health for European people. The impact can be estimated as change in all-causes, cardiovascular and respiratory mortality for short-term exposure to ozone and particles, considering short-term effect, usually particles have the greatest health impact.

Results show a high sensitivity to the dynamical meteorology and chemical components in the atmosphere. The impact of air pollution in the mortality is very important (percentages higher than 20 % are very common). The system offers an effective, and easy tool that is helpful within the health services organization and decision-making.

The approach is that the health impact focuses on individual compounds without considering the simultaneous exposure to several, which is what actually occurs. The interactions between different contaminants require a good knowledge of the mechanisms of toxicity for the different compounds, which is rarely available. In order to take account of co-exposure to different pollutants, it can be assumed that the health effects of individual compounds are additive. Finally the tool is based on assumptions that local situations are similar to the reference conditions used in the epidemiological studies from which the exposure-response coefficients are derived. Uncertainties at emission estimated, calculated ambient concentrations, epidemiological concentration-response relationships cannot be forgotten but the system can provide valuable and important information.

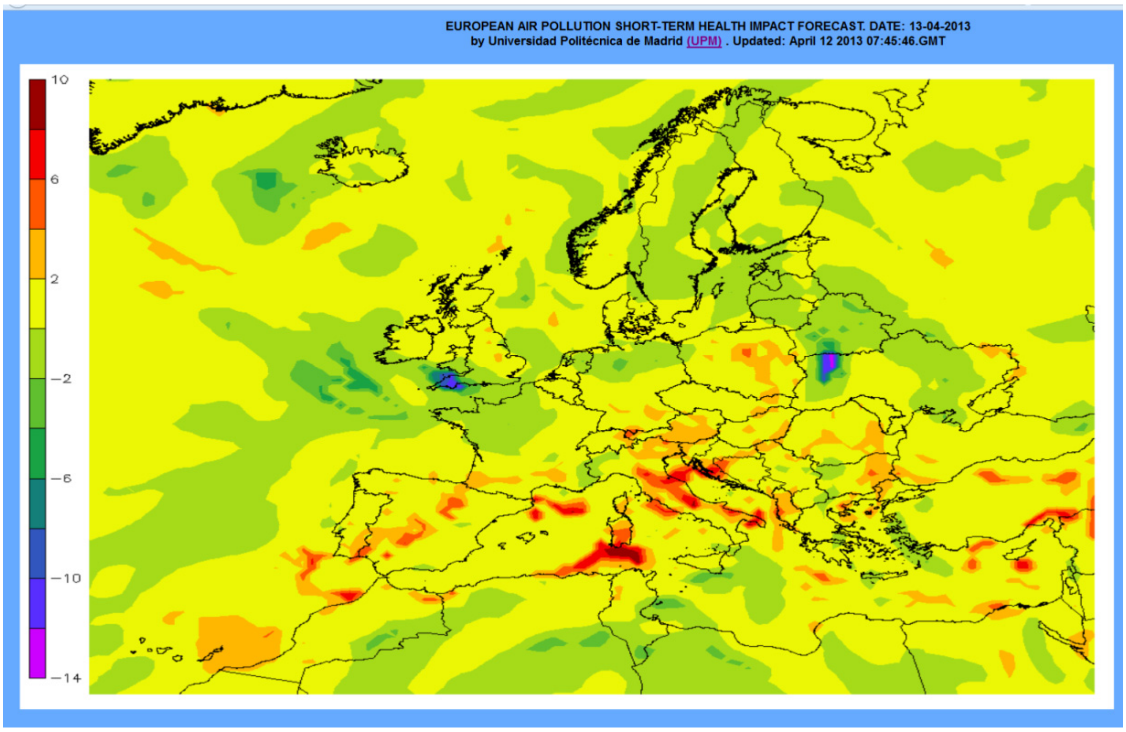
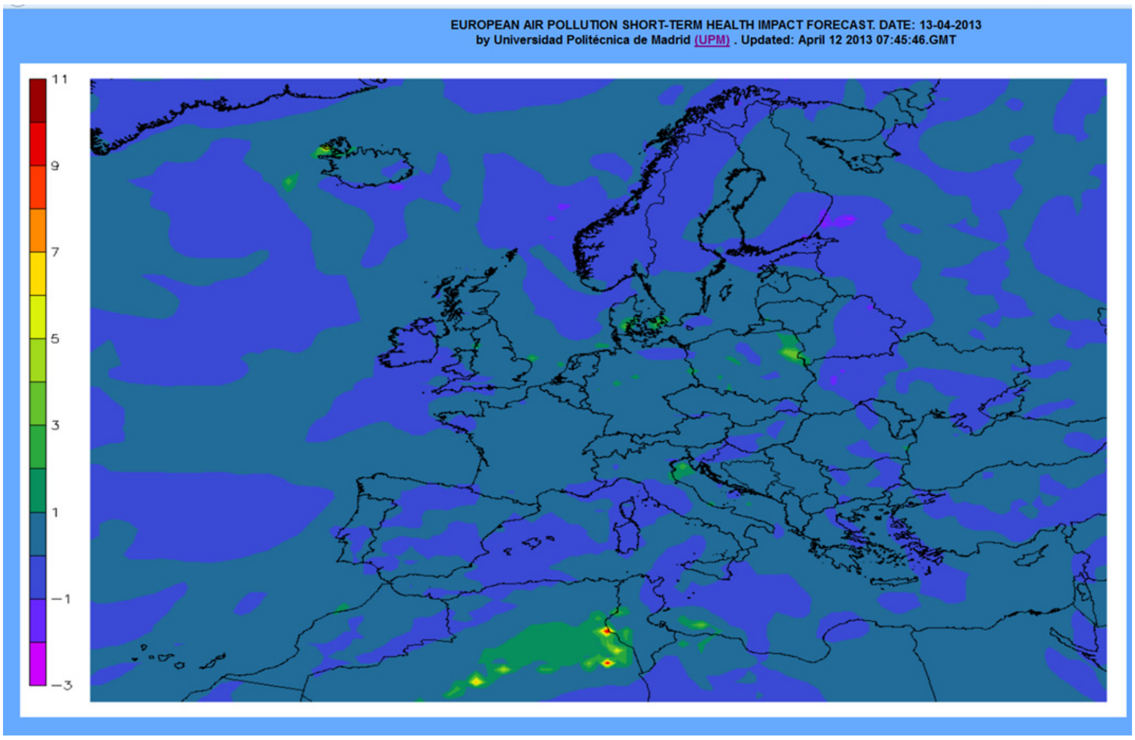


Figure 6. Example of the European air pollution short-term health impact forecast by UPM. Daily mortality change (%) by Ozone for tomorrow, April, 12, 2013.



Figrure 7. Example of the European air pollution short-term health impact forecast by UPM. Daily mortality change (%) by Particle for tomorrow, April, 12, 2013.

ACKNOWLEDGMENTS

The authors thankfully acknowledge the computer resources, technical expertise and assistance provided by the Centro de Supercomputación y Visualización de Madrid (CESVIMA) and the Spanish Supercomputing

Network (BSC). The authors also acknowledge the ESPAÑA VIRTUAL CENIT project funded by the Spanish Ministry of Science and Technology and Indra Sistemas.

REFERENCES

Byun D., J. Young, G. Gipson, J. Godowitch, F. Binkowsky, S. Roselle, B. Benjey, J. Pleim, J.K.S. Ching, J. Novak, C. Coats, T. Odman, A. Hanna, K. Alapaty, R. Mathur, J. McHenry, U. Shankar, S. Fine, A. and Xiu, C. (1998) 'Description of the Models-3 Community Multiscale Air Quality (CMAQ) model', *Proceedings of the American Meteorological Society 78th Annual Meeting Phoenix*, AZ, January 11–16, pp. 264–268.

Coats C.J., Jr. (1995) 'High Performance Algorithms in the Sparse Matrix Operator Kernel Emissions (SMOKE)' *Modelling System, Microelectronics Center of North Carolina, Environmental Systems Division*, Research Triangle Park, NC, p. 6.

Flassak T., N. Moussiopoulos. (1987), 'An application of an efficient non-hydrostatic mesoscale model', *Boundary Layer Meteorology*, 41 pp. 135–147

Grell G., J. Dudhia, D. Stauffer (1994) , 'A Description of the Fifty Generation Penn State/NCAR Mesoscale Model (MM5)' *NCAR Tech. Note*, TN-398+STR, p. 117.

Lipfert, F. W., (1994), 'Air Pollution and Community Health.'. *Van Nostrand Reinhold*.

San José R., J.F. Prieto, N. Castellanos, J.M. Arranz, (1997), 'Sensititivity study of dry deposition fluxes in ANA air quality model over Madrid mesoscale area', *Measurements and Modelling in Environmental Pollution*, pp. 119–130.

San José, R. J.I. Peña, J.L. Pérez, R.M. González, (2003), 'EMIMO: An Emission Model'. ISBN: 3-540-00840-3, Springer-Verlag, pp. 292–298.

Worl Health Organisation (WHO) ,(1995), 'European Centre for environment and health. Concern for Europe's tomorrow.*'Health and the environment in the European Region.* Stuttgart, Wissenschaftliche Verlagsgesellschaft.

World Health Organisation (WHO). (2000a) 'Air Quality Guidelines for Europe', Copenhagen, *WHO Regional Office for Europe*, 2nd Ed.

World Health Organisation (WHO). (2000b). 'Guidelines for Air Quality', *WHO, Geneva.*

World Health Organisation (WHO), (2003). 'Health Aspects of Air Pollution with Particulate Matter, Ozone and Nitrogen Dioxide' *WHO, Regional Office for Europe*, Copenhagen(EUR/03/5042688)

Williams A, M. Caughey, H.-C. Huang, X.-Z. Liang, K. Kunkel, Z. Tao, S. Larson, D. Wuebbles, (2001), 'Comparison of emissions processing by EM-S95 and SMOKE over the Midwestern US'*, Preprint of International Emission Inventory Conference: One Atmosphere, One Inventory*, Many Challenges. Denver, CO, May 1–3, pp. 1–13.