OPERATIONAL SHORT TERM HEALTH IMPACT ASSESMENT OF AIR POLLUTION MODELLING SYSTEM OVER EUROPE

R. San José, Juan L. Pérez[1] and Rosa M. González[2]

[1]Environmental Software and Modelling Group, Computer Science School, Technical University of Madrid (UPM), Campus de Montegancedo, Boadilla del Monte, 28660 Madrid (Spain).
[2]Department of Geophysics and Meteorology, Faculty of Physics, Complutense University of Madrid (UCM), Ciudad Universitaria, 28040 Madrid (Spain

Abstract: The last decade scientific studies have indicated an association between air pollution to which people are exposed and wide range of adverse health outcomes. We have developed a tool which is based on a model (MM5-CMAQ) running over Europe with 50 km spatial resolution, based on EMEP annual emissions, to produce a short-term forecast of the impact on health. 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. Finally, we have derived the relationship between concentration change and mortality change from the C-R function which is the final health impact function.

Key words: *Health, air pollution, MM5, CMAQ, relative risk, epidemiological studies, C-R functions*

INTRODUCTION

Much of the population lives in areas where the concentration of air pollution reaches levels that affect health (WHO, 1995). Numerous epidemiological studies have already shown that exposure to elevated levels of various ambient pollutants. 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. Air pollution is a complex mixture of various substances. However, most epidemiological studies find a range of health outcomes to be consistently related to particulate matter (WHO, 2003).

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.

The conceptual basis for the estimation of human health impacts is: changes in air quality levels are related to changes in incidence levels for a particular health effect. It accomplishes this by running health impact functions, which relate a change in the concentration of a pollutant with change in the incidence of a health point. For example, in the case of a premature mortality health impact functions may take into account: air pollution change, mortality effect estimate. Air quality change is calculated as the difference between tomorrow and today. The mortality effect estimate is an estimate of the percentage change in mortality due to a one unit change in ambient air pollution. This is done taking into account the concentration-response (C-R) function based of epidemiology studies.

The exposure-response function is the key contribution of epidemiology to the health impact assessment. The functions are reported as a relative risk for a given change in exposure. Exposure-response functions have been derived from published meta-analyses. The following health outcomes were selected, based on the availability of the exposure-reactions functions: total premature mortality, excluding accidents and violent deaths, cardiovascular mortality and respiratory mortality.

The present system forecast the short term health impact of air quality, PM10 and O3, over Europe on the health outcomes. So 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.

METHODS

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, Equation 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.

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

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

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. 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. Figure. 4 shows a example of the capabilities of the system.

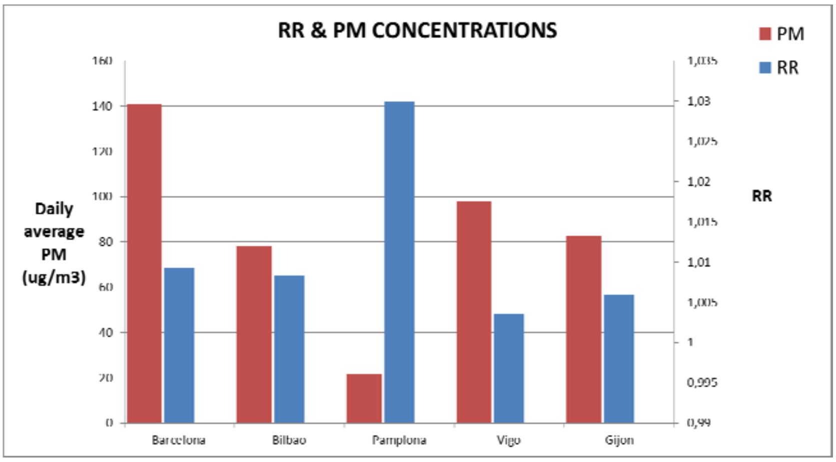


Figure 1: RR and PM10 daily average for all causes mortality

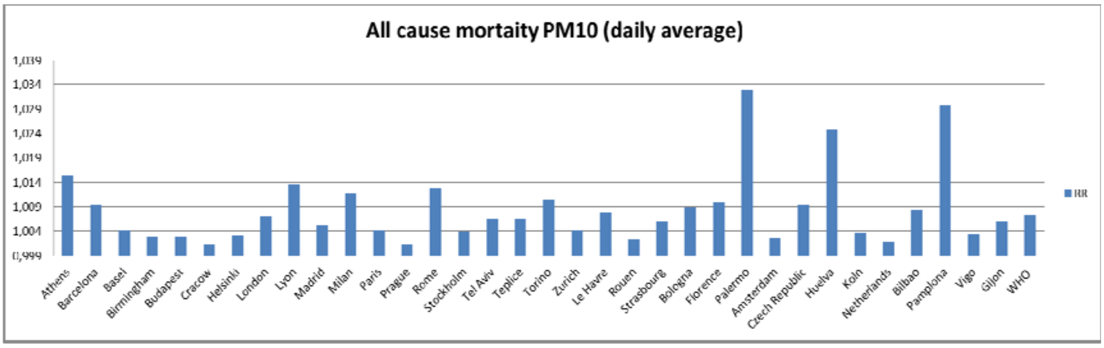


Figure 2: RR for all causes mortality for the PM10 daily average

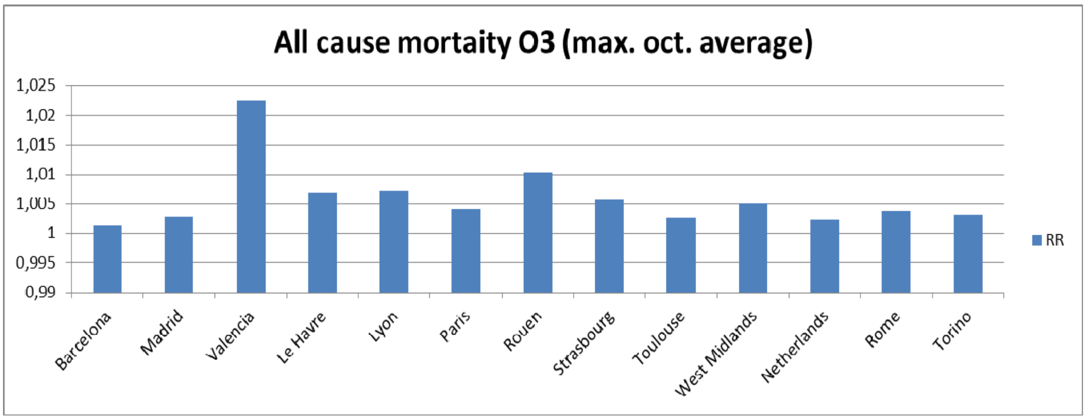
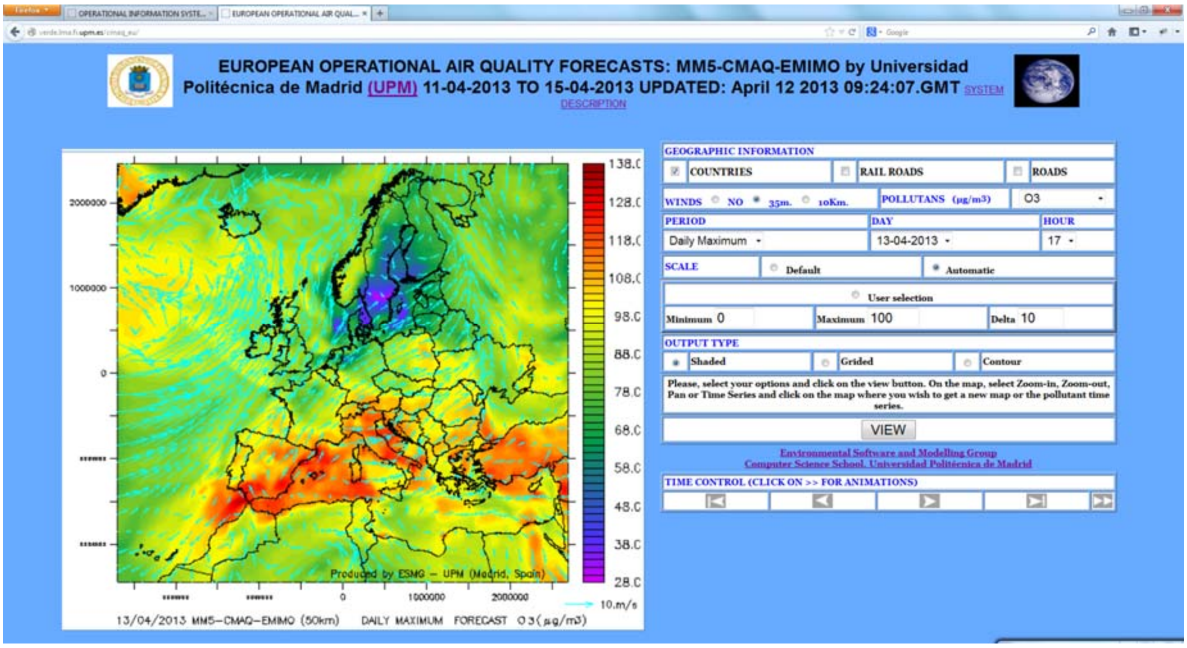


Figure 3: RR for all causes mortality for the O3 maximum octoh. average

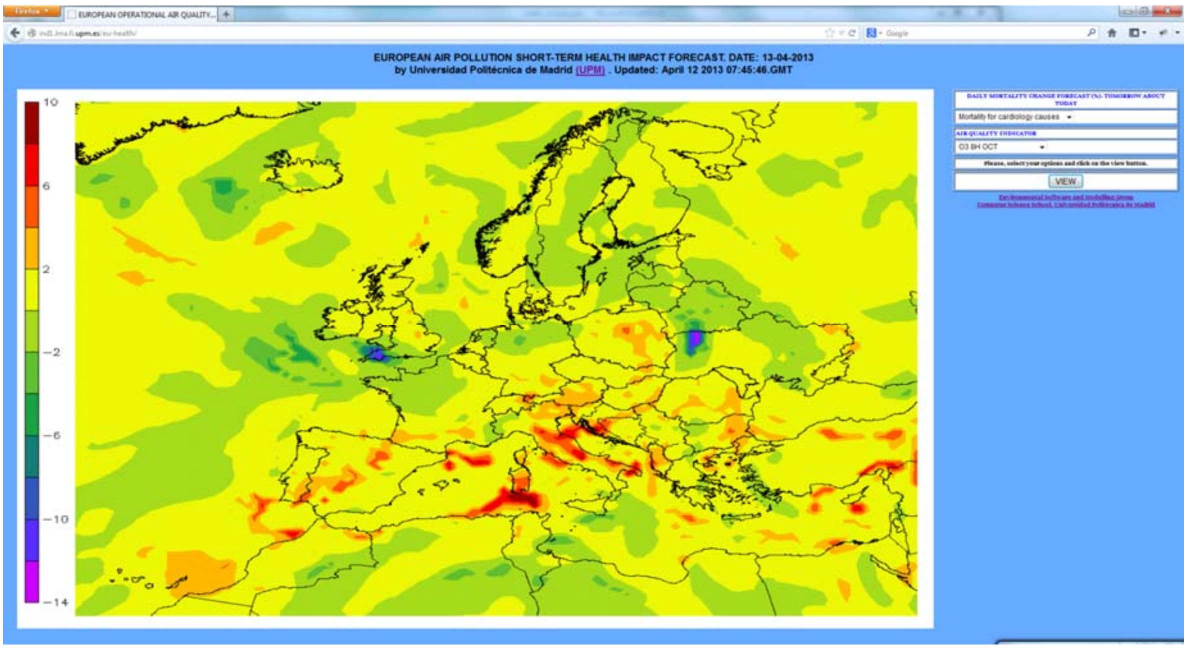


Figrure 4: European Operational Air Quality Forecasts by using MM5–CMAQ–EMIMO (OPANA V3) for April, 13, 2013 for Ozone maxima.

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.

RESULTS AND CONCLUSIONS

Figure 5 show a example of forecast daily mortality change (%) by Ozone for tomorrow, April, 12, 2013 related to today. It is mortality for cardiology causes with Ozone 8H air quality indicator.



Figrure 5: Example of the European air pollution short-term health impact forecast by UPM

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. 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).

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. Xiu, C. Lang, Description of the Models-3 Community Multiscale Air Quality (CMAQ) model, in: Proceedings of the American Meteorological Society 78th Annual Meeting Phoenix, AZ, January 11–16, 1998, 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. An application of an efficient non-hydrostatic mesoscale model. Boundary Layer Meteorology, 41 (1987), pp. 135–147

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

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

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

San José, R. J.I. Peña, J.L. Pérez, R.M. González, EMIMO: An Emission Model. ISBN: 3-540-00840-3, Springer-Verlag, 2003, 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, 2000.

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, 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, 2001, pp. 1–13.