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Project description: High resolution environmental modelling and evaluation programme for Croatia (EMEP4HR)[1]

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The international project Environmental Modelling and Evaluation Programme for Croatia (EMEP4HR) is presented. It is a joint project of Norwegian and Croatian meteorological services, University of Zagreb and Energy Research and Environmental Protection Institute (EKONERG) that started in 2006, and is due to last until 2010. The main purpose of this project is to develop and test an operative framework for environmental control of air pollution problems in Croatia. The project will allow for a stable long-term development of Croatia's scientific capacity to support the design of environmental protection strategies. Among objectives of EMEP4HR project is an implementation of a new scheme for vertical diffusion calculation. The new approach in calculating vertical diffusion coefficient $K(z)$ is a linear-exponential function with convenient analytic properties. It is a generalized form of O'Brien's third-order polynomial $K(z)$ that is presently being used in the EMEP model. Initial results of the EMEP4HR show the feasibility of this project. This project will allow Croatian experts to produce their own assessments of air quality at national and at urban level.

Keywords: international project, Eulerian chemical model, vertical diffusion, environmental protection

1. Introduction

Air pollution has become important issue of our lifes due to continous and long-term effect on human health, esspecially in urban conditions. Dangerous emissions are recognized, particularly: sulphur dioxide, nitrogen oxides, vola-

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tile organic compounds, ammonia and particulate matter. In order to estimate air pollution negative impacts on population it is important to know emission sources characteristics as well as pollution transport mechanisms. For that purpose many different chemical transport models have been developed. Among these, for over 20 years, the European Monitoring and Evaluation Programme (EMEP) under the Convention on Long-Range Transboundary Air Pollution (LRTAP), has been responsible for developing air quality modelling systems to support the design of environmental control strategies in Europe.

The Unified EMEP model was developed at the Norwegian Meteorological Institute under the EMEP programme. It simulates atmospheric transport and deposition of acidifying and eutrophying compounds, as well as photo-oxidans and particulate matter over Europe (Simpson et al., 2003; Tarrasón et al., 2003). The model domain covers Europe and the Atlantic Ocean with the grid size 50×50 km^2, while in the vertical there are a 20 terrain following layers reaching up to 100 hPa. The Unified EMEP models uses 3-hourly meteorological data from PARallel Limited Area Model with Polar Stereographic map projection (PARLAM–PS), a dedicated version for EMEP of the HIgh Resolution Limited Area Model (HIRLAM) model.

The EMEP model provides unique information that complements monitoring data, such as: a) calculation on the origin of air pollutants (EMEP, 2005), and b) analysis of future emission scenarios. Although many other modelling tools have emerged within the scientific community over the years, the results from the EMEP model continue to be the reference data for the development of environmental policies at European scale.

The Environmental Modelling and Evaluation Programme for Croatia (EMEP4HR) project is a joint project of Norwegian and Croatian meteorological services, University of Zagreb and Energy Research and Environmental Protection Institute (EKONERG) that started in 2006, and is due to last until 2010. The main purpose of this project is to develop and test an operative framework for environmental control of air pollution problems in Croatia. The project will allow for a stable long-term development of Croatia's scientific capacity to support the design of environmental protection strategies. In particular, the main objectives of this project involve:

- the development of high resolution emission inventories of air pollutants in Croatia and in selected urban areas,
- the implementation and further development of a mesoscale version of the Eulerian EMEP Unified chemical transport model coupled with the Aire Limitée Adaptation dynamique Développement InterNational (ALADIN), numerical weather prediction model (Geleyn et al., 1992), and the Weather Research and Forecasting (WRF) model (Skamarock et al., 2005),
- the development of a new capability for the assessment of urban air quality in main Croatian cities,

– the evaluation and testing of the new modeling capability according to international standards.

In order to accomplish these tasks high resolution emission inventories need to be compiled. The EMEP model has to be further extended in order to include meteorological effects that are much more important on the finer spatial scale, such as turbulence and convection generated by a complex terrain, imposing large differences in vertical eddy fluxes over short distances.

2. Emission inventory compilation

The quality of emission estimates is essential to any air quality assessment. In particular, for mesoscale applications, special attention should be given to guarantee the quality of both the extent and the spatial distribution of emission data.

The EKONERG is responsible for compilation of official Croatian emission data reported to international conventions, like the European Community and at United Nations Economic Commission for Europe (UN ECE) Convention on Long-Range Transboundary Air Pollution (LRTAP). The participation of the institute will ensure that the methods developed during this project are discussed and adopted by the Croatian emissions experts.

The work begins with the evaluation of existing emission data in regional scale. The development of a methodology for allocation of emissions in fine scale, complemented with the compilation of activity data and emission data from local and national authorities is under progress and will result in the elaboration of gridded emission inventories in 10×10 km^2 resolution for Croatia. This work will also lead to the development of the urban gridded emission inventories in 1×1 km^2 for the city of Rijeka and, further on the development of emission scenarios for Croatia for 2010.

3. Mesoscale application of EMEP model in Croatia

The project proposes to implement and make a further development of a nested EMEP model version over Croatia – the EMEP4HR. It is important to quantify air quality at regional and local scale, as well as the impact of regional as compared to urban air pollution. The nested version of the EMEP model is developed recently (e.g. Wind et al., 2003) and it is suitable for national applications.

3.1 EMEP4HR model development

In order to apply the EMEP Unified Eulerian model at finer resolution, new input data for land use, gridded emissions, meteorological and climatological fields have been compiled. Pre-processing programmes have been developed in order to use ALADIN Numerical Weather Prediction (NWP) model

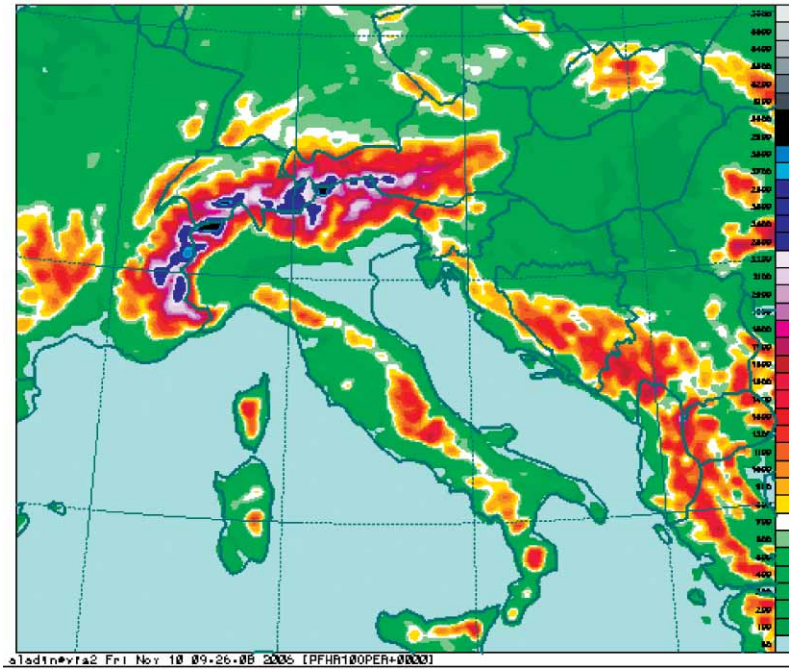

Figure1. Domain of the EMEP4HR model with 10 × 10 km^2 horizontal resolution.

developed by Aladin consortium, as EMEP4HR meteorological driver at 10 km resolution. The EMEP4HR model will be applied on a new domain presented in Figure1.

The quality of the high resolution input data should make a big impact on chemical transport model performance at this scale. Therefore it is very important to test and validate this model setup, which is a next step in this part of the project. An initial validation of the new set-up of the EMEP model in Croatia is presently under progress.

3.2 Implementation of new vertical diffusion scheme in the EMEP model

As part of the model development in the project, the Croatian team at the Meteorological and Hydrological Service in Croatia (MHSC) is responsible for testing the vertical exchange of the model and its capability to reproduce observed vertical profiles of pollution also in complex terrain applications.

Presently, the EMEP model uses a simple K-theory parameterisation for vertical diffusion. The vertical diffusion coefficient, *K(z)*, is first calculated throughout the domain with Blackadar (1979) method. Then, the Richardson number method is used to determine stability conditions. In stable conditions

$K(z)$ is set to minimal value $K(z) = 0.001$ m^2 s^{-1} and it is constant all through the domain. In unstable conditions $K(z)$ is calculated according to O'Brien (1970) formula.

A new approach of vertical exchange in the EMEP model uses generalized form of the O'Brien's third-order polynomial $K(z)$. It is a linear-exponential function with convenient analytic properties (Grisogono and Oerlemans, 2002):

$$K(z) = (K_{MAX} e^{1/2} / h) z \exp[-0.5(z / h)^2] \quad (1)$$

The new schemes, called Grisogono, and the operational scheme, called O'Brien, have been validated for January and July 2001. For verification, surface measurements of different chemical elements in EMEP domain are used. The number of used EMEP stations (S) varied from about 45 to 80, and the number of measured data (N) varied from about 1400 to 2250 (Table 1). Correlation coefficients, root mean square error (RMSE) and BIAS values between the measurements and the modelled O'Brien and Grisogono daily concentrations are presented (Table 1). Correlation coefficients are similar especially in July but RMSE and BIAS are smaller significantly for colder part

Table 1. Correlation coefficients, RMSE and BIAS values between the modelled and the measured daily NO_2, SO_2 and SO_4 surface concentrations for January and July in 2001. Modelled concentrations are calculated with O'Brien and Grisogono vertical diffusion schemes. S – the number of used EMEP stations, N – the number of measured daily concentrations.

	January		**July**	
	S	**N**	**S**	**N**
NO_2	46	1390	47	1430
SO_2	71	2130	72	2073
SO_4	78	2238	80	2253
$K(z)$ scheme	O'Brien	Grisogono	O'Brien	Grisogono
	Correlation coefficients			
NO_2	0.57	0.55	0.48	0.48
SO_2	0.47	0.49	0.22	0.23
SO_4	0.65	0.67	0.55	0.55
	RMSE			
NO_2	2.45	2.34	1.17	1.19
SO_2	2.96	0.89	0.87	0.83
SO_4	0.88	0.84	0.7	0.72
	BIAS (%)			
NO_2	22	4	–32	–44
SO_2	86	85	–6	–10
SO_4	14	12	–13	–11

of the year for Grisogono scheme. This implies that random and systematic errors in the model are smaller with Grisogono method. It should also be pointed out that BIAS of SO_2 in winter is very high > 80% with both methods, indicating that other factors (e.g., emissions) greatly affect the results.

First evaluation of the results show that although the new scheme is performing better over the O'Brien scheme, the EMEP model does not show significant differences in correlation coefficients, RMSE and BIAS values. This may be due to two reasons: (i) the model is not sensitive enough on vertical diffusion at 50×50 km^2 horizontal resolution, and/or (ii) statistical methods used to validate the results are inappropriate for the cause, thus some other statistical parameters that show spatial and time differences between two data sets i.e. empirical orthogonal function (EOF) should be used to compare the two schemes.

4. Conclusion

Initial results of the EMEP4HR show the feasibility of this project. This project will allow Croatian experts to produce their own assessments of air quality at national and at urban level, evaluate the national consequences of proposed international environmental control options, analyze the effect of future emission scenarios and identify new instruments for implementation of the air quality standards in Croatia. The research work will be carried out as a contribution to the UNECE Convention on Long-Range Transboundary Air Pollution and will facilitate the integration of Croatia to conform to European Community air quality regulations.

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SAŽETAK

Opis projekta: Program modeliranja i procjene kakvoće zraka za područje Hrvatske na finoj rezoluciji (EMEP4HR)

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Predstavljen je međunarodni projekt: 'Environmental Modelling and Evaluation Programme for Croatia' (EMEP4HR), odnosno: 'Program modeliranja i procjene kvalitete zraka za područje Hrvatske na finoj rezoluciji'. Radi se o zajedničkom projektu Norveške i Hrvatske meteorološke službe, Sveučilišta u Zagrebu i Instituta za energiju i zaštitu okoliša (EKONERG) u vremenskom trajanju od 2006 do 2010 godine. Osnovni zadatak ovoga projekta je razvoj i verifikacija sustava za modeliranje kakvoće zraka na području Hrvatske u svrhu njegove operativne primjene u području praćenja i planiranja zaštite okoliša od atmosferskog onečišćenja. Projekt će omogućiti stabilni, dugoročni razvoj hrvatskih stručnih i znanstvenih kapaciteta koji će podupirati sustav i strategiju zaštite okoliša. Jedan od ciljeva EMEP4HR projekta je izrada detaljnog katastra emisije onečišćujućih tvari na finoj rezoluciji: 10 km × 10 km na području cijele Hrvatske i 1 km × 1 km u urbanim središtima (Zagreb i Rijeka), te razvoj modela transporta i disperzije polutanata primjenom novih shema za proračun koeficijenta vertikalne, $K(z)$, i horizontalne, $K(x,y)$, difuzije koji će uvažavati specifičnosti našega podneblja i topografskih uvjeta. Nova metoda proračuna vertikalne difuzije temelji se na linearnoj-eksponencijalnoj funkciji poznatih analitičkih svojstava, a ujedno predstavlja opći oblik O'Brienovog polinoma trećeg reda, trenutno je u fazi verifikacije u operativnoj verziji modela. Inicijalni rezultati pokazuju dobre rezultate i izvedivost projekta. Osim što će omogućiti hrvatskim stručnjacima razvoj alata za modeliranje i procjenu kakvoće zraka na državnoj razini, projekt će omogućiti i razvoj modela za predviđanje i simulaciju uvjeta onečišćenja u urbanim i industrijski razvijenim središtima.

Ključne riječi: međunarodni projekt, eulerovski kemijski model, vertikalna difuzija, zaštita okoliša

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