EMS Annual Meeting Abstracts,
Vol. 6, EMS2009-418, 2009
9th EMS / 9th ECAM

9th EMS Annual Meeting
9th European Conference on Applications of Meteorology
High resolution meteorology
- applications and services

Air quality over Europe and Iberian Peninsula for 2004 at high horizontal resolution: evaluation of the CALIOPE modelling system

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In the frame of the CALIOPE project (Baldasano et al., 2008a), a high-resolution air quality forecasting system, WRF-ARW/HERMES/CMAQ/DREAM, is under development and applied to the European domain (12km x 12km, 1hr) as well as to the Iberian Peninsula domain (4km x 4km, 1hr) to provide air quality forecasts for Spain (http://www.bsc.es/caliope/). The simulation of such high-resolution model system is possible by its implementation on the MareNostrum supercomputer. To reassure potential users and reduce uncertainties, the model system must be evaluated to assess its performances in terms of air quality levels and dynamics reproducibility.

The present contribution describes a thorough quantitative evaluation study performed for a reference year (2004). CALIOPE is a complex system that integrates a variety of environmental models. WRF-ARW provides high-resolution meteorological fields to the system. It is configured with 38 vertical layers reaching up to 50 hPa. Meteorological initial and boundary conditions are obtained from the NCEP final analysis data. The HERMES emission model (Baldasano et al., 2008b) computes the emissions for the Iberian Peninsula simulation at 4 km horizontal resolution every hour using a bottom-up approach. For the European domain, HERMES disaggregates the EMEP expert emission inventory for 2004. The CMAQ chemical transport model solves the physico-chemical processes in the system. The vertical resolution of CMAQ for gas-phase and aerosols has been increased from 8 to 15 layers in order to simulate vertical exchanges more accurately. Chemical boundary conditions are provided by the LMDz-INCA2 global climate-chemistry model (see Hauglustaine et al., 2004). Finally, the DREAM model simulates long-range transport of mineral dust over the domains under study.

In order to evaluate the performances of the CALIOPE system, model simulations were compared with ground-based measurements from the EMEP and Spanish air quality networks. For the European domain, 45 stations have been used to evaluate NO2, 60 for O3, 39 for SO2, 25 for PM10 and 16 for PM2.5. On the other hand, the Iberian Peninsula domain has been evaluated against 75 NO2 stations, 84 O3 stations, 69 for SO2, and 46 for PM10. Such large number of observations allows us to provide a detailed discussion of the model skills over quite different geographical locations and meteorological situations.

The model simulation for Europe satisfactorily reproduces O3 concentrations throughout the year with small errors: monthly MNGE values range from 13% to 24%, and MNBE values show a slight negative bias ranging from -15% to 0%. These values lie within the range defined by the US-EPA guidelines (MNGE: +/- 30-35%; MNBE: +/- 10-15%). The reproduction of SO2 concentrations is relatively correct but false peaks are reported (mean MNBE=22%). The simulated variation of particulate matter is reliable, with a mean correlation of 0.5. False peaks were reduced by use of an improved 8-bin aerosol description in the DREAM dust model, but mean aerosol levels are still underestimated. This problem is most probably related to uncertainties in our knowledge of the sources and in the description of organic aerosols. The nested high-resolution simulation of Spain (4 km) shows a very good agreement with observations for O3 (monthly MNGE range from 13 to 19%). Particulate matter results are in agreement with the European simulation, and a net improvement on nitrate and sulphate is observed in several stations in Spain. Such high-resolution simulation will allow analysing the small scale features observed over Spain.

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