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A long-term evaluation study of the atmospheric dynamics of aerosols and gaseous species over Europe using an integrated air quality modelling system with high resolution

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Both urban/suburban and rural areas of Europe are impacted by air pollution, especially by particulate mater (PM10 and PM2.5) and ozone. Long-term exposure to air pollution increases mortality, risk of chronic respiratory illness and risk of developing cancer. Under this umbrella, the Caliope project been developed and implemented an air quality forecasting system with a high resolution for Europe (12 km and 1-hr) and Spain (4 km and 1-hr), allowing to increase the knowledge on dynamics of pollutants to reduce the impacts of air pollution on human health. Hence, model evaluation becomes essential for assessing the performance of the model when reproduce air quality levels and dynamics and in order to assure the potential users' confidence.

This study focuses on the evaluation of the ability of Caliope air quality modelling system (based on WRF-ARW/EMEP/CMAQ/DREAM models and implemented in the MareNostrum supercomputer) to represent the dynamics of atmospheric pollutants over Europe (domain covering 5760 x 4800 km2, 12 km resolution, 32 vertical layers in the troposphere) for the entire year 2004, using the CMAQ chemistry-transport model for gas-phase and aerosols. Emissions are disaggregated from the EMEP expert emission inventory for 2004 to the used resolution using the criteria implemented in the HERMES emission model. Regarding the boundary conditions (BCs) sensitivity

tests, Appel et al. (2007) show that the model performance for O3 improved when using global BCs instead of default profiles; therefore the BCs are based on monthly-specific profiles for Europe and not in climate profiles.

Comparisons to selected measurement sites of EMEP are used for quality control of atmospheric concentrations. Information available has been analysed choosing stations with 85% data completeness of the annual cycle. Uncertain data before and later a stopped and calibration of measurement equipment have been removed. Primary pollutants evaluation is performed using daily data, because of the lack of stations reporting hourly data (NO2, 37 stations; SO2, 40 stations; PM10, 26 stations; PM2.5; 17 stations). On the other hand, O3 presents 70 stations with hourly data. Accordingly to previous studies in Europe of single and inter-comparison model evaluation, a suit of discrete statistics as Mean Normalized Bias Error (MNBE), Mean Normalized Gross Error (MNGE) and Root Mean Square Error (RMSE) has been used in order to characterized the model behaviour; also categorical statistics or skill scores based on Eder et al. (2006) have been implemented to test the capability of the model to simulate concentration exceeding thresholds (>180 ug m-3 for ozone and >20 ug m-3 for the rest of pollutants).

The model has a good skill to simulate gaseous and aerosols species with relative small error in a year cycle (MNGE between 17% to 47%) and slightly negative bias (MNBE ranging from -21% to -11%). Model simulations are more accurate during summer months (JJA) than during winter (DJF), with a MNGE between 15-21% in the warmest season. The model errors increase in stations near the boundaries domain, such as Norway (MNGE>35%) with the best performance in mid-southern latitudes (MNGE around 25% for all species). Result evaluation using skill score shows that the general accuracy in simulating exceedances (Accuracy, A) is around 60%. For all the species the model shows a poor behaviour when simulating concentrations over the fixed threshold, presenting a Critical Success Index (CSI) under 25 %; at the same time this high values are underestimated (Bias, B<1). The model shows a better behaviour in simulating concentration below the fixed threshold (CSI around 60%).

The overall conclusion from this study is that the model presents a good behaviour for O3 simulation according to US EPA guidelines (MNBE< +/-15% and MNGE<35%) and European Directive 2002/3/EC criteria (Uncertainty<50%). Although annual average model simulation of PM is according to European Directive 1999/30/EC (Uncertainty<50%) and to Unified EMEP model (EMEP, 2006b) (both with RMSE between 9 to 14 ug m-3), the model presents the highest deviations for particle matter prediction. This problem is related to the uncertainty in our knowledge of the sources, dynamical or chemical processes. The same conclusion is obtained in previous works for several European models under the framework of the CityDelta project (Vautard et al., 2007) and Unified EMEP model evaluation in 2004 (EMEP, 2006a; 2006b).