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Sources and development of photochemical episodes in Central Europe: An evaluation study of the WRF-Chem model

Saskia Buchholz (1,2), Klaus Görgen (1), and Günther Heinemann (2)

(1) Centre de Recherche Public – Gabriel Lippmann, Departement Environnement et Agro-Biotechnologies , 41, rue du Brill, L-4422 Belvaux, Luxembourg, (2) University of Trier, VI – Geography/Geosciences, Department Environmental Meteorology, Behringstraße 21, D-54286 Trier, Germany

The fully coupled Weather Research and Forecasting model with online chemistry (WRF-Chem) is used to study the model's ability to reproduce observed meteorological and air pollution patterns in Central Europe. In this context the evaluation study shall help to better understand processes behind ambient air quality and to identify the origin of air pollution episodes. Model simulations are performed for six summertime photochemical episodes with different ozone concentrations over Northwest Continental Europe. This forms the basis of future work that will focus on the understanding of the differences between those episodes and the impact of the weather patterns that cause particularly the high photochemical episodes in August 2003 and July 2006.
Simulations are performed for two one-way nested model domains of 27 km and 9 km horizontal resolution extending over 40 vertical layers up to 50 hPa. The initial and boundary meteorological conditions are provided every 6 hours by ECMWF ERA-Interim reanalyses. The chemistry package consists of the Regional Acid Deposition Model version 2 (RADM2) for gas-phase chemistry and Mandronich photolysis scheme. Aerosol dynamics and reactions are represented via the combination of the Modal Aerosol-Dynamics Model for Europe and the Secondary Organic Aerosol Model (MADE/SORGAM).
A main step of the WRF-Chem model implementation and setup over Europe is the conversion of available anthropogenic emission inventories to the WRF-Chem data format. This further includes the transformation of chemical and aerosol species, the vertical distribution of emissions, as well as a time split from annual emission into hourly emissions. European anthropogenic emissions are provided from the GEMS (Global and regional Earth-system Monitoring using Satellite and in-situ data) project.
Each model simulation is validated against different meteorological and chemical observations. The evaluation of the results for the 27 km domain is based on the ENSEMBLES project 0.25-degree gridded daily dataset (version 3.0) of surface mean temperature and total precipitation and ENVISAT/SCIAMACHY NO2 tropospheric column densities. The 9 km domain is evaluated with selected surface observations of ozone (O3), nitrogen dioxide (NO2) and particulate matter (PM10), as well as ozonesonde and radiosonde data. The spatial patterns of the simulated near surface average air temperature are in good agreement with the observations, showing a small negative bias in most of the simulations. The comparison of model results with O3 and NO2 observations show that the magnitudes and timings of the diurnal cycles are generally consistent with each other. PM10 mass concentrations are not well represented by the model. A reason for this discrepancy may be attributed to the large uncertainties in particulate matter emissions in the anthropogenic emission inventories, often underestimating and neglecting important emission sources like uncovered dumping sites, erosion processes and wild fires.