High-resolution and urbanised LM simulations applied to air pollution forecasts for selected air pollution episodes

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Very high-resolution meteorological input data (1km resolution and below) are requested for air quality and dispersion modelling in emergency preparedness and information systems. With a growing part of the world population living in conurbations, NWP data are increasingly demanded and applied for the urban environment as well. The central task in air pollution modelling at the DWD is providing forecasts for the national nuclear emergency systems but scientific studies and operational customer demands are also carried out. DWD developed a trajectory model (TM), a Lagrangian particle dispersion model (LPDM) and a mixing height (MH) pre-processor using output of DWD's NWP models Globalmodell and Lokalmodell. In the European FP5 project FUMAPEX (Integrated Systems for Forecasting Urban Meteorology, Air Pollution and Population Exposure), Lokalmodell (LM) forecasts were scaled down to 1.1km by triple LM nesting and evaluated and inter-compared for air pollution episodes in Helsinki, Oslo, Valencia and Bologna (Fay and Neunhäuserer, 2005b; Fay et al., 2004, 2005). First LM urbanisation steps of urbanised physiographic parameters and an added anthropogenic heat source (without adapting or urbanising the LM turbulence scheme itself) were successfully applied to the April 2002 Helsinki episode (Neunhäuserer et al., 2006).

The trajectory model (TM), the Lagrangian particle dispersion model (LPDM) and the mixing height (MH) scheme use direct model output of the NWP models without interfaces and were adapted for high resolution of 2.8 and 1.1km with 45 vertical layers (operational 7km/35 layers). They were tested for air pollution episodes in Helsinki and Oslo, the TM and MH also for Valencia, and for the urbanised LM Helsinki simulations. In mountainous Valencia and Oslo, TM and LPDM simulations are very sensitive to grid resolution: 1.1 km simulations generally show improved topographic influence (channelling, blocking, much more localised mesoscale re-circulations in Valencia, Fig. 1) compared to the 7 km forecasts (Fay et al., 2005, Ødegård et al., 2005).

The MH scheme uses a gradient Richardson number approach based on the LM turbulent kinetic energy scheme and investigates the stability of individual NWP model layers (Fay et al., 1997). The results (Fay and Neunhäuserer, 2005a) show a very distinct influence of improved topography leading to enhanced structure of MH fields and a correct general decrease of MHs due to higher topography in mountainous areas. As validated previously for lower resolution, the non-urbanised and highly-resolved MH scheme generally performs well for daytime mixing heights for the FUMAPEX episodes in different climates and seasons. In cases of multiple inversion layers, an extension of the scheme to incorporate several vertically staggered boundary heights is needed. The scheme does, however, fail (like other schemes) for the strong stability and extremely strong and shallow (100 to 200m) Helsinki inversions persisting even during the day in the Helsinki Dec 1995 episode. These are approximated e.g. by LM vertical profiles of potential temperature and TKE but the MH scheme must intrinsically fail due to the strong continuous stability in all layers up to at least 1000m. This confirms the need for improvements in the scheme and its default values for the night-time and especially for stable (not only nocturnal) conditions.

The influence of the LM urbanisation measures is just visible in the near-surface trajectory paths for the Helsinki spring episode. As trajectories are determined from grid-scale winds they are much less sensitive to the thermal and sub-grid scale urbanisation effects than LPDM and MH. Increased turbulence and vertical velocity enlarge the general dimensions of the LPDM plume, show the effect of the increased land-sea circulation (Fig.2, left section) and partially large local impacts of urbanisation measures on the concentration distribution. The qualities of the MH scheme and the LM itself are also clearly shown in the successful simulation of a comprehensive heat island effect in LM parameters and fluxes (Neunhäuserer et al., 2006) leading to distinctly increased mixing heights above the city and its lee away from the coast, but even many kilometres downwind for the Helsinki 2002 episode (Fig.2, right section).

These episode and sensitivity studies show that the dispersion models are consistently formulated without the need of intermediate interface modules to the NWP models. Increased resolution and initial urbanisation measures in the LM, thus, directly lead to distinctly improved and urbanised results including an urban heat island effect in all dispersion models.

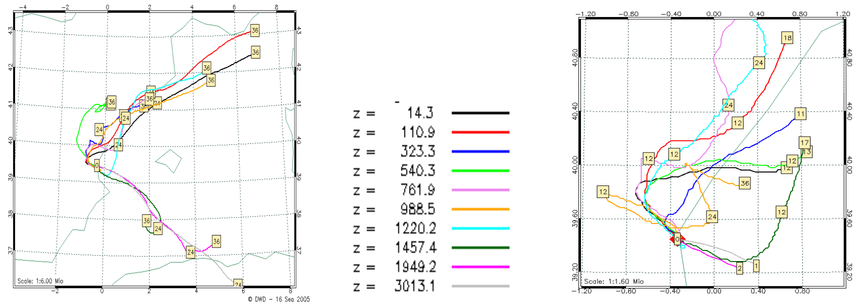

Fig. 1: LM trajectories starting at identical station at height z [m] on Valencia coast, Spain, 28 Sep 1999, 11UTC. Left: 7km, right: 1.1km resol. with improved local re-circulation leading to increased pollution levels.

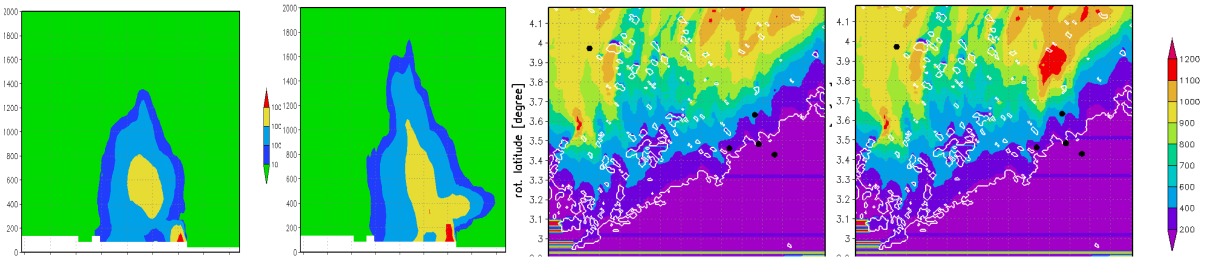

Fig. 2. Heat island above Helsinki for LPDM (left section) and MH (right section), 1.1km resolution, each comparing non-urbanised operational version (left) with urbanised version (urbanis. physiographic param. and anthropog. heat source of 60W/m² (right). LPDM: vertical cross-section of plume above Helsinki with increased sea breeze effect, 10 Apr 2002,00UTC+15h. MH: higher urban MH away from coast and drifted downwind from city (4 black dots are city obs stations), in [m] above model orography, 10 Apr 2002, 00UTC +36h.

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