SIMULATION OF THE METEOROLOGICAL CONDITIONS DURING A WINTER SMOG EPISODE IN THE INN VALLEY WITH MM5

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Abstract: The PSU/NCAR mesoscale model known as MM5, version 3.7, is used to simulate the period January 31, 2004, until February 9, 2004, when elevated pollution levels were observed in the Inn Valley. The synoptic situation which led to the elevated pollution levels in the simulation period will be briefly outlined. The MM5 model was used with the modifications provided by G. Zängl and with two different boundary layer schemes. The modelled meteorological parameters serve as input to the CAMx Eulerian chemistry model. First results of the model simulations are presented.

Keywords: *MM5, CAMx, air pollution, boundary-layer schemes, Inn Valley*

1. INTRODUCTION

In the context of the EU Alpine Space Interreg programme, the project ALPNAP (http://www.alpnap.org/) is devoted to the demonstration of scientific methods for air pollution and noise investigation along major Alpine transit routes Seibert et al. (2005). The Brenner route with the Inn Valley (Tyrol, Austria) and the Eisack-Etsch/Adige Valley (Italy), and the Frejus route with the Maurienne Valley (France) and the Susa Valley (Italy) are target areas in this project. In large valleys like those mentioned above, unfavourable dispersion conditions prevail in winter. Wind velocities are low and the atmosphere is very stable, so that pollutants emitted tend to accumulate near the valley floor and may cause exceedance of air pollution limits. Numerical models are one option to investigate such situations and the impact of emission-side measures. However, in the Alpine topography it is difficult to achieve realistic simulations of the flows. Zängl's Alpine version of MM5 Zängl (2003) has opened new possibilities for such simulations. Meanwhile the latest version of MM5 (MM5 V3.7) has incorporated several of Zängl's improvements, most notably the horizontal diffusion of temperature along z-levels instead of along σ-levels, and the shading by topography.

The simulation period was selected according to several criteria which had to be fullfilled. The simulation period should contain elevated, but not necessarily extreme levels of air pollution and it should be in the cold season. As the IMK-IFU (Garmisch) is carrying out a simulation for the whole year 2004 with MCCM in the ALPNAP project, it shoud also be in 2004 to allow comparisons. The first screening was done using PM and NO_2 exceedances in Tyrol. The thresholds of the daily means of the elevated pollutions levels where definded with more than 50 for PM10 and more than 80 $\mu g\,m^{-3}$ for NO_2 at a couple of stations in the Inn Valley. With respect to these criteria three periods were found. The period around Christmas 2004 (December 20 to December 25) was found to be not representative due to vacations in Austria, another period in December 2004 and a period in February 2004 were not only significant in the Inn Valley but also in the French and the Italian target area of the ALPNAP project. We decided to use the February period (January 31 to February 6) due to more sunshine in the valley and a tendency towards diurnal cycles of the valley wind. The simulation period starts on January 27, 12 UTC, and ends on February 9, 00 UTC. Results shall be compared with wind and temperature observations along the valley and mountain stations measurements, and with soundings of the Innsbruck airport. Atmospheric chemistry and dispersion was simulated with the CAMx (The Comprehensive Air Quality Model with extensions) chemistry model (http://www.camx.com/, Krüger (2004)).

2. MM5 AND CAMx SET-UP

The PSU/NCAR mesoscale model MM5 (Dudhia (1993); Grell et al. (1996)) version 3.7 was used with the modifications based on G. Zängl's Alpine MM5 version (Zängl (2003)) to simulate a one-week episode during February 2004. Simulations shown here are based on a grid distance of 2.4 km in the innermost nest. It is planned to add a simulation with 0.8 km resolution. The output of MM5 serves as input for the dispersion and atmospheric chemistry simulation with the Eulerian photochemical dispersion model CAMx (Environ (2006)). The chemistry mechanism used in this study is CBM-IV. Similar to the MM5 model two-way nesting is used here. The domain sizes in the MM5 model are relatively large due to the special requirements of the CAMx model. Four (next step: five) domains were used for the MM5 model starting with an 64.8 x 64.8 km^2 resolution for the European wide domain down to a 2.4 x 2.4 km^2 (0.8 x 0.8 km^2) resolution to the domain of interest covering the lower Inn Valley. In the vertical we use 35 levels. The meteorological fields and the air quality output have a temporal resolution of 1 hour.

Two different boundary-layer schemes are used and compared. In the first run, whose results are presented here, the MRF PBL scheme, based on a K profile with Troen-Mahrt representation of the countergradient term in the well-mixed PBL, is used. In the second run, the ETA scheme, based on the Mellor-Yamada scheme with TKE as prognostic variable, is used.

The MM5 model was initialized with and nudged towards ECMWF analyses. It run on a dual opteron shared-memory workstation with the PGI fortran compiler and OpenMP. The model run for the whole period was finished after 6.6 days of calculation. The CAMx model run is done on a 8-processor machine where it took 6 h.

Table 1: Overview of model grids.

Domain	Grid resolution	No. of grid boxes		domain size
		MM5	CAMx	MM5
Domain 1	64.8 km x 64.8 km	50 x 70	48 x 68	3240 x 4536 km^2
Domain 2	21.6 km x 21.6 km	85 x 94	80 x 89	1836 x 2030.4 km^2
Domain 3	7.2 km x 7.2 km	124 x 142	119 x 128	892.8 x 1022.4 km^2
Domain 4	2.4 km x 2.4 km	115 x 142	83 x 110	276 x 340.8 km^2
Domain 5	0.8 km x 0.8 km	88 x 169	83 x 164	70.4 x 135.2 km^2

3. BRIEF SYNOPTIC DESCRIPTION

The simulation starts on January 27 and ends on February 9 2004, with the main period from January 30 to February 8. The main period is a typical high-pressure situation with stable stratification in the Inn Valley. From January 27 to 28 a continental low pressure centre influences the weather pattern, on January 29 Austria lies in a northwesterly flow with showers. With the beginning of the main periode on January 30 a small high pressure system over Central Europe causes more or less clear sky conditions. The westerly flow on January 31 advects warmer air aloft, but in the valleys cold air is still remaining. From February 1 to February 3, a southwesterly flow with strong winds brings warm air from the Atlantic ocean to the Alps mainly at higher levels. From February 4 until February 6 a high pressure system with very warm Atlantic air influences the Alpine weather whereas in the bottom layer of Alpine Valleys in the western part of Austria cold air pools and cold nights provide conditions for elevated levels of pollutants. On February 7, the weather situation changes to westerly winds resulting in light rainfall and decreasing temperature, and later on a strong northwesterly flow advects cold and humid air with snowfall towards the Alps and finishes the pollution episode.

4. FIRST RESULTS

A first comparison between measured and modelled meteorological parameters has been done for the whole period of the MRF PBL run and of the ETA run. Also a comparison with the NCEP reanalysis charts of the modelling period has been carried out for selected days.

Measurements of the NO_2 station in Innsbruck compared with meteorological measurements of the University station in Innsbruck (Fig. 1) and the first results of the MM5 MRF PBL scheme and CAMx NO_2 (values in ppm) results for February 5, 2004, one of the peak days in the modelling period, are shown (Fig. 2).

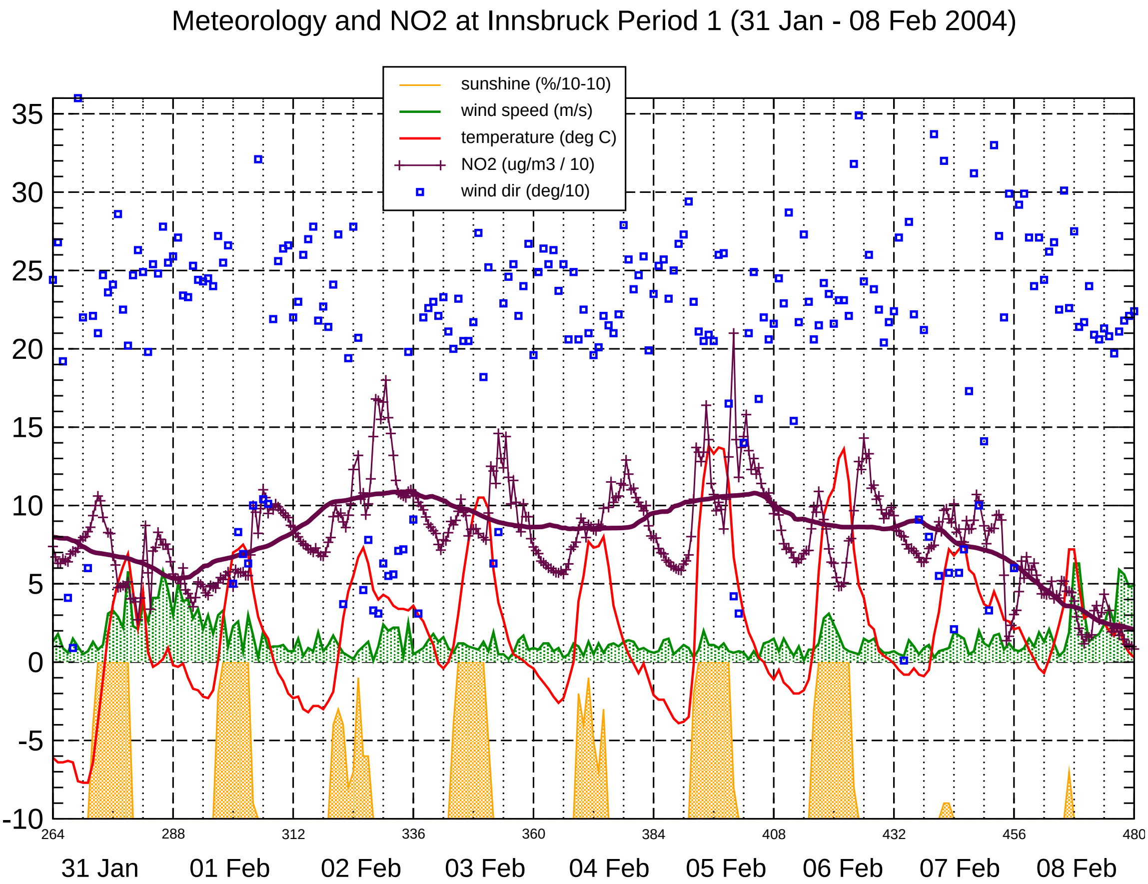

Figure 1: Observed temperature, wind speed, wind direction and percentage of sunshine of the University Innsbruck and NO_2 concentration at the measuremend site Innsbruck-Fallmerayerstrasse in the modelling period.

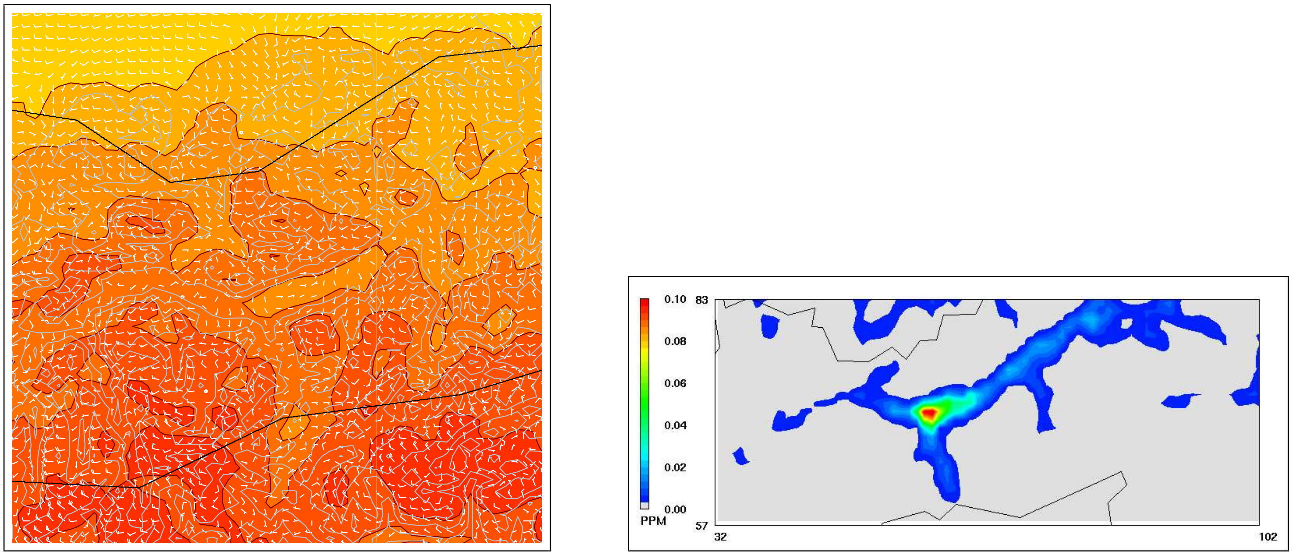

Figure 2: Left: MM5 model output on February 5, 2004, 16 UTC, of the MRF PBL run. The potential temperature (colored, dark red contour lines in 2 K distance) and wind vectors both at the lowest model level (in white) and terrain height (contour interval 500 m, in grey) of MM5 domain 4 for the Inn Valley are shown, boundaries of Austria/Tyrol in black. Values for θ range from 290 K (orange) to 301 K (dark red). Right: CAMx concentrations (values in 1/10 $\mu g\, m^{-3}$) in the first model layer on February 5, 2004, 16 UTC for the Inn Valley.

Fig.2 shows the MM5 model output of February 5, 16 UTC. The wind direction on the mountains with its westerly flow is well representated by the model, in the Inn Valley the wind has a weak in-valley flow and on the mountain slopes downslope winds dominate. These model results are in accordance with the measured conditions. A stable stratification is simulated with the MM5 model and also observed at this time. The difference of θ in the measurements between Innsbruck and Patscherkofel is 6 K the difference in the model output is not more than 4 K. This underestimation of the stability is probably an effect of the smoothing by the 2.4 km topography. The CAMx results for the Inn Valley and the area around Innsbruck represent the elevated level of pollutants in the Inn Valley and the Wipp Valley. Especially the Wipp Valley, where the Brenner motorway is located, higher pollution is simulated compared to other side valleys of the Inn Valley. The maximum values around Innsbruck are caused by the emissions of the city. The pollution in the Inn Valley has a realistic diurnal cycle, according to first analyses of the CAMx output.

In general, the MRF PBL run overestimates the geopotential height at 500 hPa but the general circulation is in good accordance with the NCEP reanalysis charts. The results of the ETA scheme also overestimate the geopotential height, but, compared to the MRF PBL run, they agree better. The comparison of θ, the potential temperature, the horizontal wind and other parameters show that the ETA run represents the Alpine Valley structure better than the MRF PBL run. Also slope winds are better represented in the ETA run.

5. CONCLUSIONS

Simulations have been carried out with MM5 and CAMx for a 10 day winter smog period in the Inn Valley with a resolution of 2.4 km. The first results for the innermost domain of the MM5 model run are in general agreement with the measured meteorological parameters and also the first results of the CAMx model for the Inn Valley and the Wipp Valley are realistic. A first comparison between ETA and MRF PBL scheme run shows that the ETA scheme produces better results than the MRF scheme especially in the Alpine area. Extension to 0.8 km and a detailed evaluation are planned.

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