EVALUATION OF THE OPERATIONAL OZONE FORECAST MODEL OF THE ZAMG WITH MEASUREMENTS OF THE AUSTRIAN AIR QUALITY NETWORK

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Abstract: Operational model forecasts of ozone concentrations are compared to the observations of about 150 air quality stations in Austria. Evaluations of the last three summers revealed that exceedances of the information threshold could be predicted quite well by the model. Investigation of a heat period in summer 2006 indicates possible sources of precursors. The Lagrangian particle model LASAT (www.janicke.de) is used additionally to the chemical model CAMx (www.camx.com) to show the dispersion of the plumes of stacks with high emissions of NOx in the vicinity of Vienna.
For two months in summer 2007 sensitivity studies with different input parameters were performed. Model runs with different parameterisations for the vertical diffusion coefficient (Kv) are conducted and experiments with different values of the minimum values of Kv in the lower levels show the influence of this parameter on the nocturnal ozone decrease for different sites. Different model runs with variable boundary conditions at the top of the modelling domain as well as variable total ozone column data are performed.

***Key words:** ALADIN-CAMx, operational ozone forecasts, evaluation with air quality stations, case studies, sensitivity studies.*

1. INTRODUCTION

The operational regional weather forecast model ALADIN of the Central Institute for Meteorology and Geodynamics (ZAMG) is used in combination with the chemical transport model CAMx to conduct forecasts of tropospheric ozone over Europe. The operational ozone forecasts have been run since 2005 in cooperation with the University of Natural Resources and Applied Life Sciences in Vienna (BOKU). The model is run with a resolution of 9.7 km for the finest grid covering Austria and parts of neighbouring countries. The outer model domain expands over large areas of Europe. ALADIN-Austria provides weather forecasts on an hourly basis – 48-hour forecasts are used.

2. MODEL COMPONENTS

The air quality model system consists mainly of three parts that are linked together: the meteorological model ALADIN, the emission model that converts different emission inventories to the modelling grid and the dispersion model CAMx (Fig. 1).

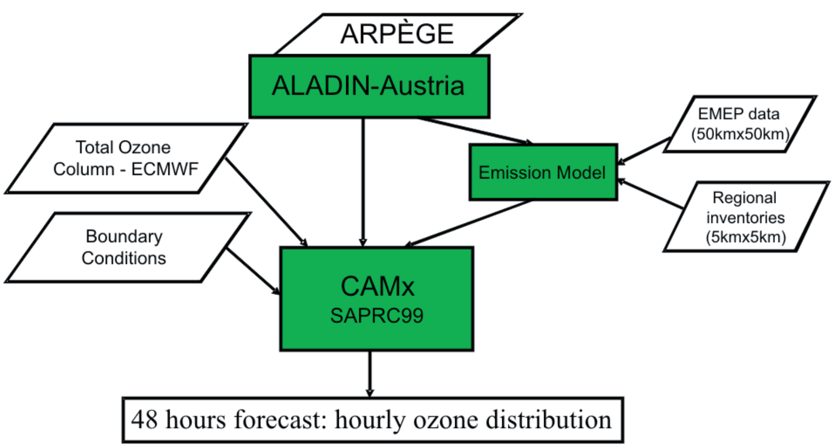

Figure 1. ALADIN-CAMx – air quality modelling system.

CAMx (v4.40, Comprehensive Air qualtity Model with extensions) simulates the emission, dispersion, chemical reaction, and removal of pollutants in the troposphere by solving the pollutant continuity equation for each chemical species on a system of nested 3D grids. A two-grid nesting is used with a coarse grid over Europe and a finer grid for the core area covering Austria (Fig.2) with the best possible spatial resolution of 9.7 km (according to the present grid of ALADIN-Austria).

The meteorological fields are supplied by the limited area model ALADIN-Austria (http://www.cnrm.meteo.fr/aladin/). It is run twice a day at the ZAMG and renders forecasts for 72 hours. The meteorological fields have a temporal resolution of one hour. The data is provided on 60 model-levels and has a horizontal resolution of 9.7 km. Fields of wind, temperature, pressure, convective and large scale precipitation, snow cover, solar radiation and specific humidity are extracted directly out of the ALADIN dataset. The other fields, cloud optical depth, cloud water- and precipitation water content have to be parameterised from the ALADIN output.

The model system generally uses EMEP emissions. For the countries Austria, Czech Republic, Slovakia and Hungary, the original 50 km x 50 km data are downscaled to 5 km x 5 km based on an inventory from 1995 (Winiwarter and Zueger, 1996). The EMEP data for 2004 (Vestreng et al., 2006) was used during the summer 2007. In addition, a new highly resolved emission inventory for the City of Vienna (Orthofer et al., 2005) is used for this area.

As boundary conditions for the coarse grid monthly average values are used. The concentrations were obtained from model calculations which were conducted for the EU-project CECILIA . Total ozone column data is obtained from ECMWF data.

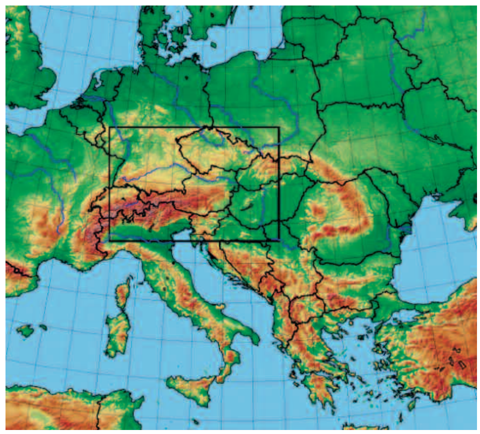

Figure 2. Coarse and fine modelling domain.

3. EVALUATION OF THE OPERATIONAL FORECASTS 2007

High ozone values are most frequently encountered in the eastern parts of Austria, where warnings for values above the information (90 ppbv) or the alarm threshold (120 ppbv) are launched for ozone region 1 (covering Lower Austria, Vienna and Burgenland).

Figure 3 shows the predicted maximum concentrations for ozone region 1 (2007). Timeseries-, Scatter and Taylordiagrams are used. The course of ozone concentration from one day and two-days model forecasts are compared to measurements (43 air quality stations).

Exceedances of the information threshold of 180 μgm^{-3} (~90 ppbv) occured in 2007 between April and August with the highest concentrations during a hot period in the middle of July. The hitrate for the prediction of the exceedance of the information threshold was 90.71% in 2007 (90.9% in 2005 and 88.00% in 2006). In 2007 an exceedance of the alarm threshold was predicted by the model for the first time.

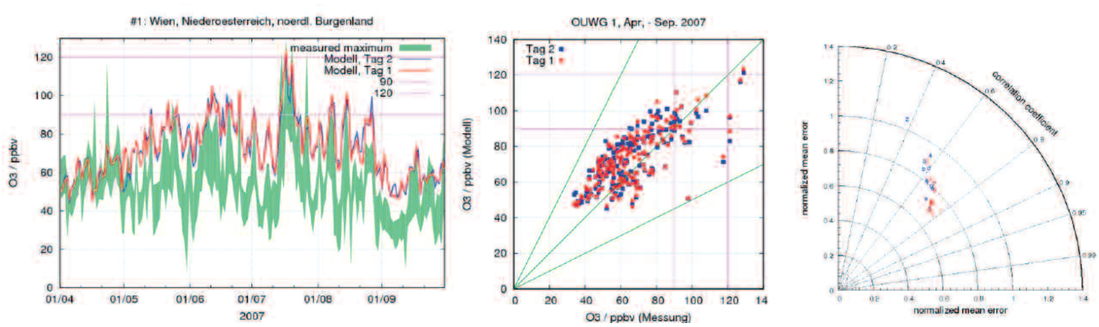

Figure 3. Timeseries-, Scatter- and Taylordiagrams of daily ozone maxima predicted versus observed in ozone region 1.

Figure 4 (left) shows the model performance depending on the absolute altitude of the measurement station. Stations situated in higher altitudes are generally less correlated with the model forecasts than stations in flat terrain. Below 500 m the correlation between model and observation reaches values up to 0.8. Figure 4 (right) also shows the dependence of the model performance on the height difference between station and grid cell height. A negative difference means that the station lies below the average grid cell height. Most of these stations are situated in valleys where strong local primary emissions occur which can reduce the ozone concentrations. If the grid cell is lower than the observation (height increment is positive), which is often the case for hill stations where only low emissions occur the model gets influenced stronger by emissions from lower levels, which leads to deviations.

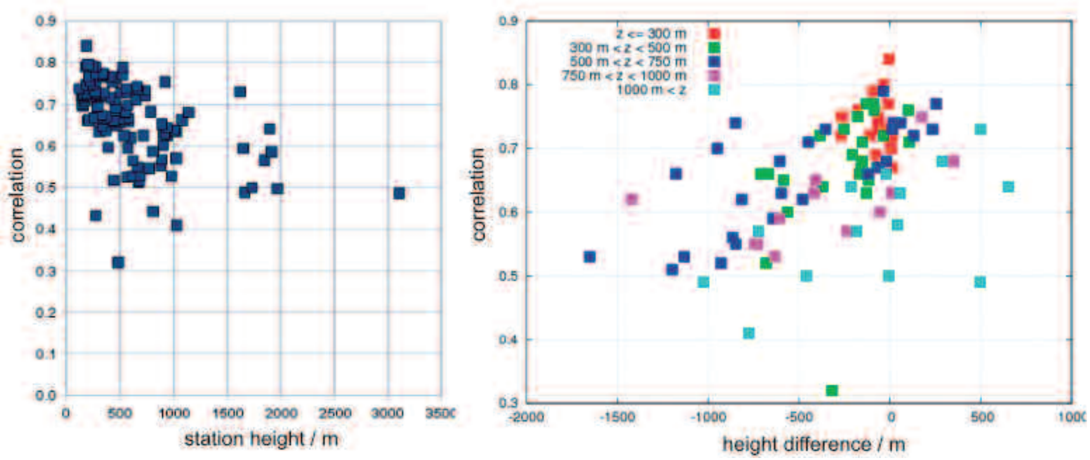

Figure 4. Correlation between observed and modelled maximum concentrations (daily) against - left: absolute station height; right: height increment between station and grid cell height.

4. CASE STUDY 2006

During a hot period in July 2006 exceedances of the alarm threshold occurred in ozone region 1 which were not predicted by the model. The highest concentrations were measured in the southwest of Vienna (Fig. 5). Analysis of the meteorological conditions show that these short intensive peaks occurred during low wind conditions and were combined with a wind turn. After this short period the ozone peak concentrations decreased to the same level that was observed at surrounding stations.

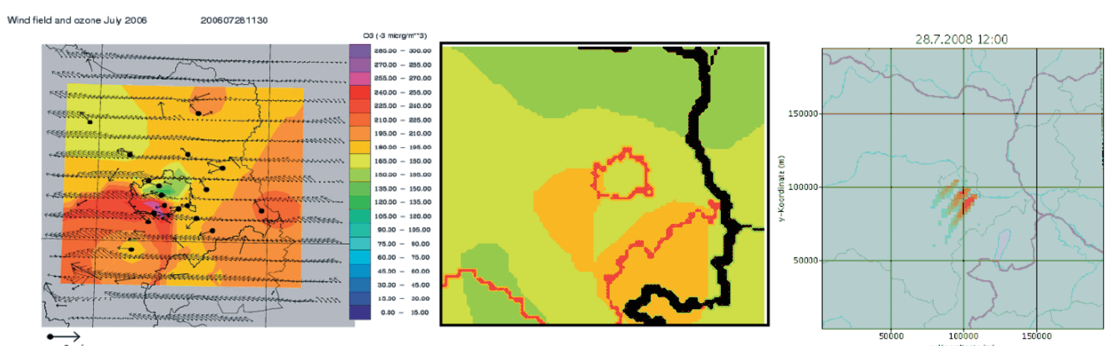

Figure 5. Left: Observed wind and ozone concentrations on 28th July at 11:30. Middle: Ozone forecast (ALADIN-CAMx) for the 28th July 12:00 2006. Right: Calculated dispersion of the plumes of the dominant industrial NOx sources in Vienna.

This episode was most likely caused by local emissions in combination with low wind conditions. In addition the Lagrangian Particle Model LASAT (Janicke, 2005) was used to investigate the dispersion of the plumes of dominant industrial sources in the vicinity of Vienna. NOx emission factors for this period were provided for the strongest industrial sites. Traffic emissions as well as chemical conversions that lead to generation of ozone could not be considered in the calculations. Fig. 5 shows that the plumes disperse with the north-easterly wind to the south-west of Vienna to the region where high ozone peaks have been observed. Although the tendency of the ozone pattern can be predicted by the air quality model ALADIN-CAMx (Fig. 5), the short ozone maxima in this limited area could not be resolved in the measured intensity in this case.

5. SENSITIVITY STUDIES

For a period of 2 months during the summer 2007 model runs were conducted to investigate the model sensitivity to different input parameters. Different parameterisations of the vertical diffusion coefficient *Kv* were used as well as different boundary conditions and compared to observations and the operational (oper) run. Table 1 shows the different parameterisations for *Kv* used in Figure 6 and Figure 7.

Table 1. Input parameters for the different methods to obtain Kv and derived parameters.

	Louis (1979)	O'Brien (1970)	Mellor and Yamada (1974, 1982)	McNider and Pielke (1981)	CMAQ, Byun (1999)
	oper	ob70	lev2	mp81	cmaq
U	X	X	X	X	X
V	X	X	X	X	X
Temperature	X	X	X	X	X
Humidity	X	X	X	X	X
Pressure	X	X	X	X	X
Mixing height		X			X
Monin-Obukhov length					X
Richardson number	X		X	X	

Additionally the following model runs were conducted:

- *kvmin*: the minimum value of Kv below 100 m is set to a value depending on the land-use data of the respective grid cell.
- *koo3*: a spatial and temporal constant value of 300 DU is used for the total ozone column instead of ECMWF forecasts.
- *topcon*: different concentrations on the top of the model domain are used.

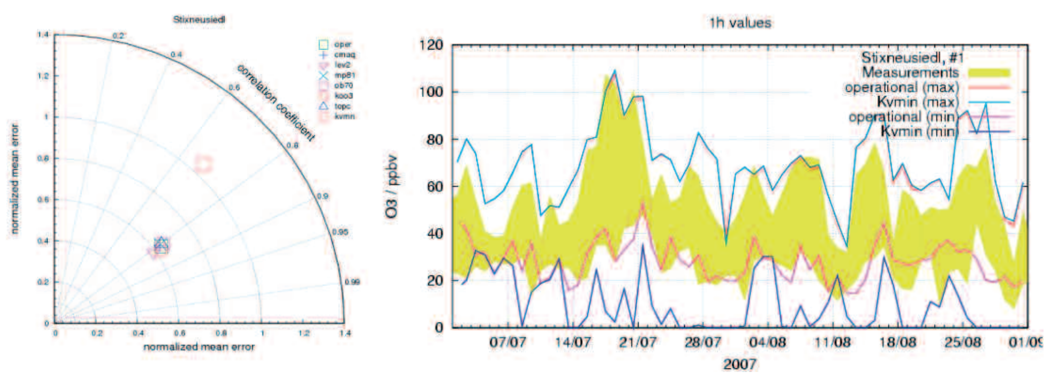

Figure 6. Comparison of observations with model calculations for the air quality station Stixneusiedl. Left: Taylor diagram of different model runs. Right: Timeseries of model runs using a minimum value of *Kv* depending on the land-use data.

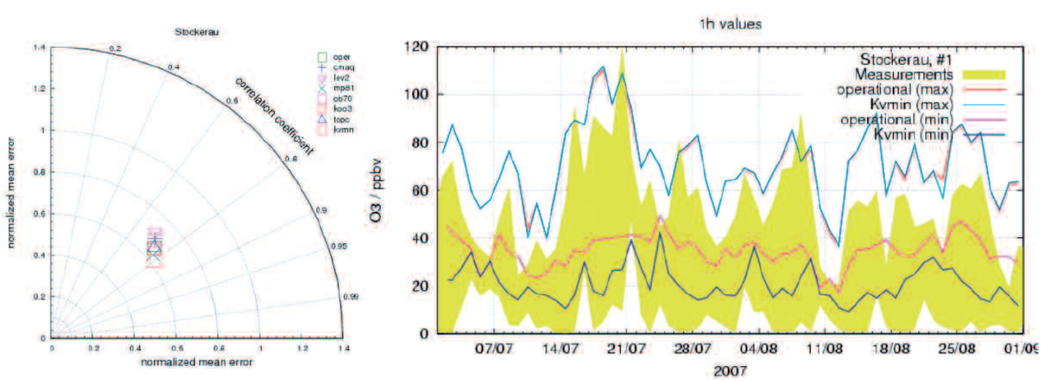

Figure 7. Comparison of observations with model calculations for the air quality station Stockerau. Left: Taylor diagram of different model runs. Right: Timeseries of model runs using a minimum value of Kv depending on the landuse data.

The Taylor diagrams in Figure 6 and Figure 7 show that for the predicted maximum concentrations the different model runs do not differ much from each other. Only the *kvmin* approach leads to worse results than the other model runs for the air quality station Stixneusiedl (Fig. 6, left).

For the station Stixneusiedl the approach with a minimum vertical diffusion coefficient *Kv* in the lower layers depending on the land-use class overestimates the nocturnal decrease of ozone and leads to worse results than the original approach which sets the minimum *Kv* value to 1 m^2s^{-1} at all grid cells. At the station Stockerau the model calculations using the variable *Kvmin* approach reproduces the minimum observations better (Fig. 7). Concerning the maximum concentrations the two methods show hardly any differences.

6. CONCLUSIONS

The Air-Quality Model ALADIN-CAMx is evaluated with measurements of operational air quality stations in Austria. Time-series-, scatter- and Taylordiagrams show the performance of the operational ozone forecasts. It can be shown that the correlation between model and observations is better for stations which have less height deviations from the grid cell than for stations in complex terrain where the height increment is large. The results that were obtained from a case study in 2006 during a hot period in the summer show that this episode was most likely caused by local emissions in combination with low wind conditions. Model runs with different parameterisations and boundary conditions show that the model is not very sensitive to these parameters concerning the prediction of daily maximum values.

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REFERENCES

Janicke, U., 2005: Ausbreitungsmodell LASAT. Referenzbuch zu Version 2.14.

Louis, J.-F., 1979: A parametric model of vertical eddy fluxes in the atmosphere. *Boundary Layer Meteorology*, **17**, 187-202.

McNider, R.T. and R.A. Pielke, 1981: Diurnal Boundary-Layer Development over Sloping Terrain. *Journal of the Atmospheric Sciences,* **38**, 2198-2212.

Mellor, G.L. and T. Yamada, 1974: A Hierarchy of Turbulence Closure Models for Planetary Boundary Layers. Geophysical Fluid Dynamics Program, Princeton University, Princeton, N.J.08540.

Mellor, G.L. and T. Yamada, 1982: Development of a Turbulence Closure Model for Geophysical Fluid Problems. *Reviews of Geophysical and Space Physics*, **20**, NO. 4, 851-875.

Monin, A.S. and A.M. Obukhov, 1954: Basic regularity in turbulent mixing in the surface layer of the atmosphere. *Akad. Nauk. S.S.S.R. Trud. Geofiz. Inst.*, Tr., **24**, 163-187.

O'Brien, J.J.,1970: A note on the Vertical Structure of Eddy Exchange Coefficient in the Planetary Boundary Layer. *Journal of Atmospheric Sciences*, **27**, No. 8, 1213-1215.

Orthofer, R., H. Humer, W. Winiwarter, P. Kutschera, W. Loibl, T. Strasser, and J. Peters-Anders, 2005: emikat.at – Emissionsdatenmanagement für die Stadt Wien. ARC system research, Bericht ARC-sys-0049, Seibersdorf, Austria, April 2005.

Vestreng, V., K. Breivik, M. Adams, A. Wagener, J. Goodwin, O. Rozovskkaya and J.M. Pacyna, 2005: Inventory Review 2005, Emission Data reported to LRTAP Convention and NEC Directive, Initial review of HMs and POPs. *Technical report MSC-W,* **1/2005**, ISSN 0804-2446.

Winiwarter, W. and J. Zueger, 1996: Pannonisches Ozonprojekt, Teilprojekt Emissionen. Endbericht. Report OEFZS-A-3817, Austrian Research Center, Seibersdorf.