ASSIMILATION OF GROUND BASED OZONE MEASUREMENTS TO IMPROVE THE AIR QUALITY FORECASTS FOR AUSTRIA

ZAMG Zentralanstalt für Meteorologie und Geodynamik

BOKU

[a]M. Hirtl, [b]B. C. Krüger, [a]E. Petz, [a]T Schöngassner, [a]C. Flandorfer
(a) Section Environmental Meteorology, ZAMG - Central Institute for Meteorology and Geodynamics, Vienna, Austria
(b) Institute of Meteorology, BOKU – University of Natural Resources and Life Sciences, Vienna, Austria

Introduction

The regional weather forecast model ALADIN-Austria of the Central Institute for Meteorology and Geodynamics (ZAMG) is used in combination with the chemical transport model CAMx (www.camx.com) to conduct forecasts of gaseous and particulate air pollutants over Austria. The forecasts which are done in cooperation with the University of Natural Resources and Applied Life Sciences in Vienna (BOKU) are supported by the regional governments since 2005.

During summer 2009 the model forecasts over-predicted the respective ozone measurements at Austrian Air Quality stations by far during certain periods. Analysis shows that the daily values of the initial conditions of the ozone concentrations are already too high compared to the observations. To account for such an over-prediction of the initial fields an optimum interpolation scheme was implemented at the ZAMG to assimilate continuously available data from about 120 Austrian Air Quality stations.

The influence of the initial conditions of ozone and NO2 is shown in this study and the evaluation of the new data assimilation scheme for a selected episode demonstrates the improvement of the model forecasts.

Model components

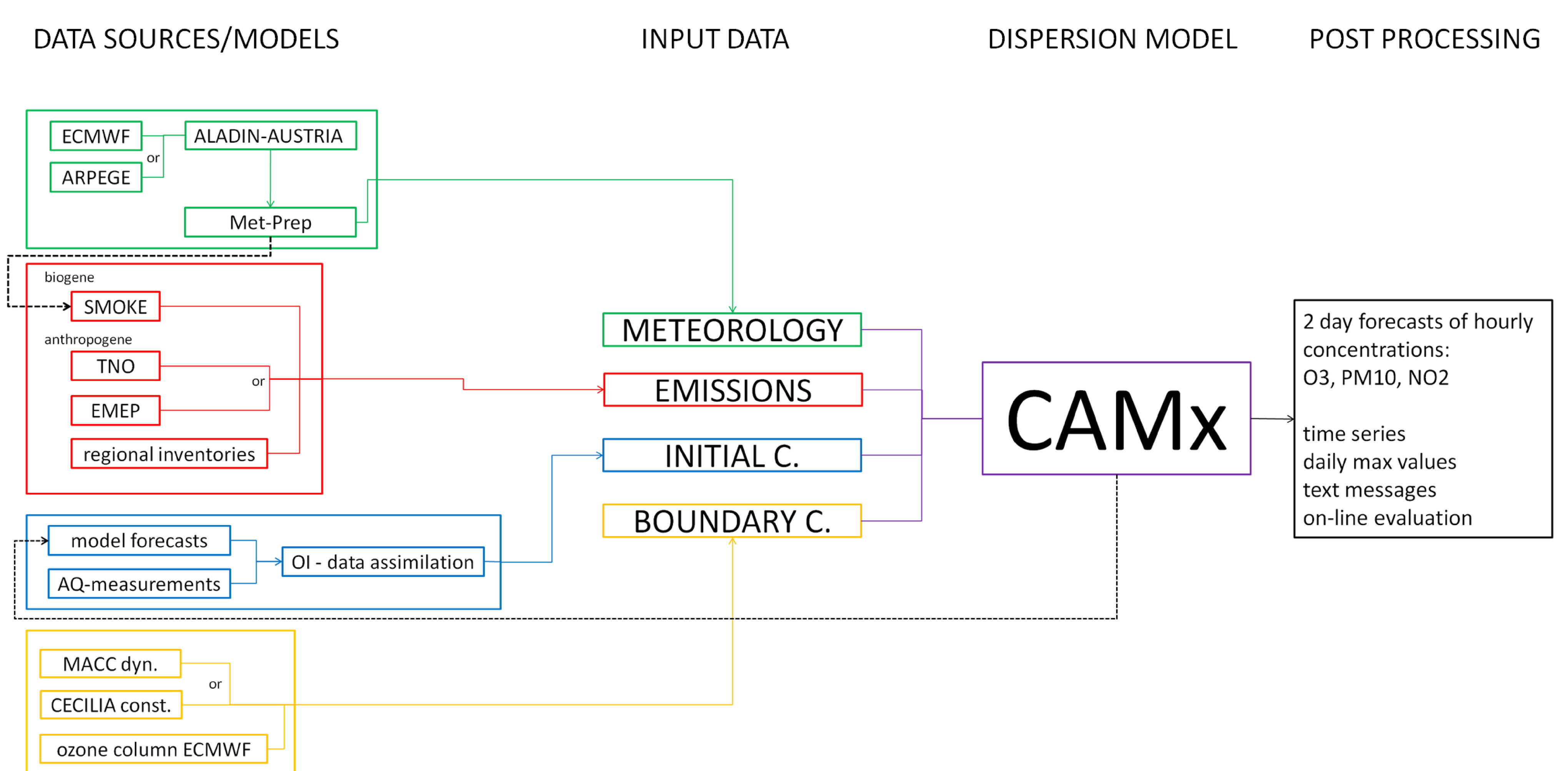


Fig. 1: AQA – Air Quality model for Austria

The model system currently uses EMEP (Vestreng et al., 2007) emissions for Europe. 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). In addition, a new highly resolved emission inventory for the City of Vienna (Orthofer et al., 2005) is used for this area. The biogenic emissions are calculated with the BEIS3 mechanism, which is implemented in the emission model SMOKE.

Monthly average concentration values (1991-2001) of the different species are used as boundary conditions for the coarse grid. The concentrations were obtained from model calculations (Krüger et al., 2008), which were conducted for the EU-project CECILIA (Central and Eastern Europe Climate Change Impact and Vulnerability Assessment, http://www.cecilia-eu.org/). Forecasts of total ozone column are provided by the ECMWF.

Influence of the initial condition

Various model runs were conducted to investigate the possible influence of the initial conditions on the concentration distribution (ozone) for a certain forecast period. The control run started with an average concentration distribution (00-UTC, „Control run"). The predicted concentrations of two runs with modified initial conditions (all grid cells were scaled with 2 and 0.5) are compared as time series to the control run. The figure 2 shows the development of the concentrations for a selected region in Austria (average concentrations in ozone region 1, north-east Austria). An additional model run considers different initial concentrations (factor 0.5) of NO2 to analyse the influence of precursor substances for that case.

The figure shows that after a about 7 days all model runs lead to the same concentration values.

It is expected that for practical applications the deviations between modeled initial conditions and measurements will not deviate that much from reality so that the memory of the model concerning the initial conditions will be less than 7 days. For the first two days of the ozone forecasts it is expected that data assimilation of ground based measurements can improve the forecast.

Assimilating NO2 (especially at 00 UTC) does not have an influence on the model simulations for the considered case.

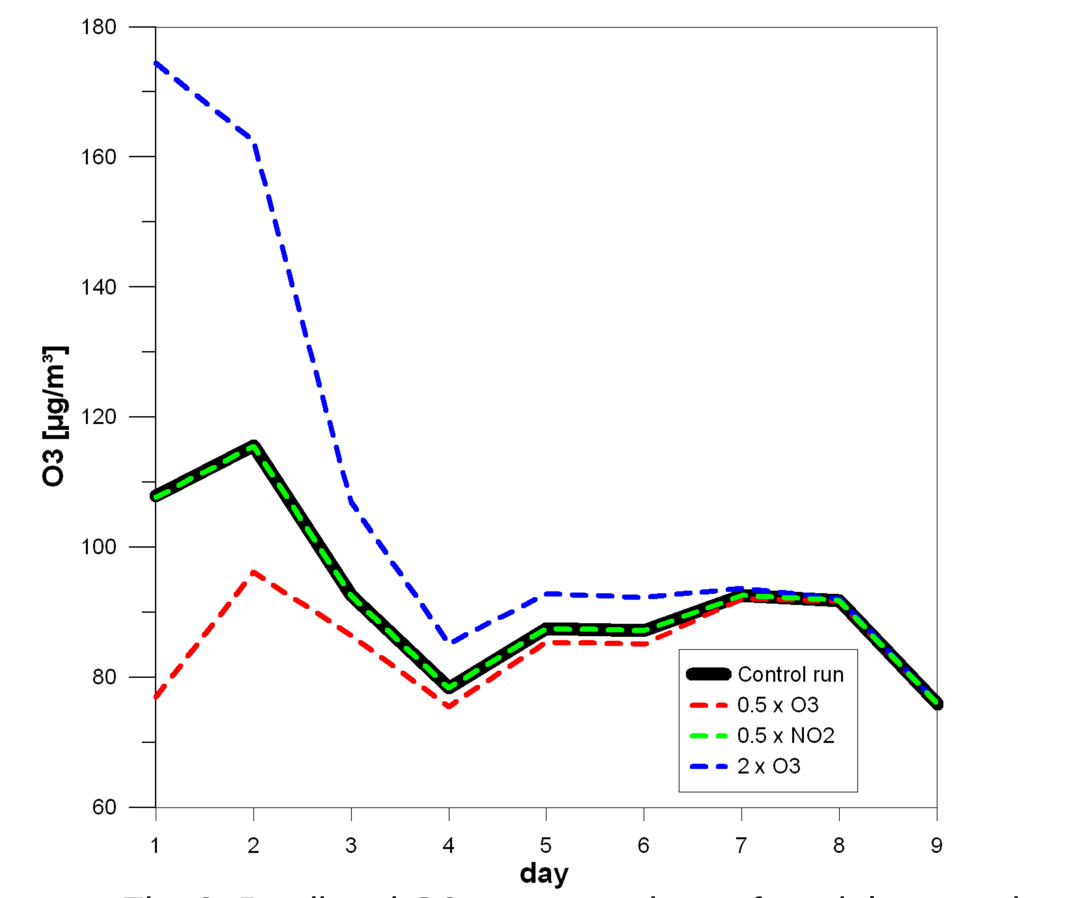
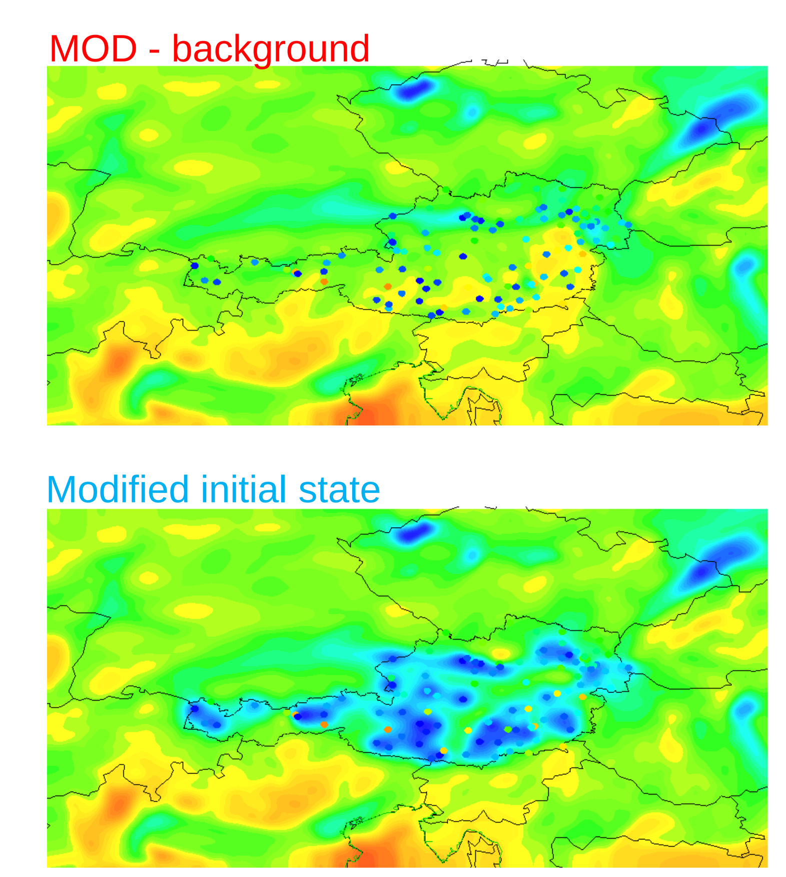


Fig. 2: Predicted O3 concentrations of model runs using different initial conditions.

Data assimilation routines for ground based ozone measurements

For the assimilation of the ozone measurements optimum interpolation routines are used. The initial conditions of the operational model runs are updated once per day (00 UTC). Ozone measurements from 115 permanent stations of the Austrian Air Quality stations network are available in real time. Elevated stations are currently rejected from the analysis.



$$f_A(\vec{r}_i) = f_B(\vec{r}_i) + \vec{W}_i^{\,T}\left[\vec{f}_O - \vec{f}_B\right]$$

$$\vec{W}_i = [\mathbf{B} + \mathbf{O}]^{-1}\vec{B}_i$$

$\vec{r}_k$	Observation location
$\vec{r}_i$	Grid cell location
$f_A(\vec{r}_i)$	Analysed value at $\vec{r}_i$
$f_B(\vec{r}_i)$	Background value at $\vec{r}_i$
$f_O(\vec{r}_k)$	Observed value at $\vec{r}_k$
$f_B(\vec{r}_k)$	Background value at $\vec{r}_k$

A	Analysis
B	Background
O	Observation
W	Weight function

No information of the vertical distribution of the concentrations except for the previous model forecasts is currently available. The profiles at every grid cell are scaled with the ratio of the ground concentrations (fa(ri)/fb(ri)).

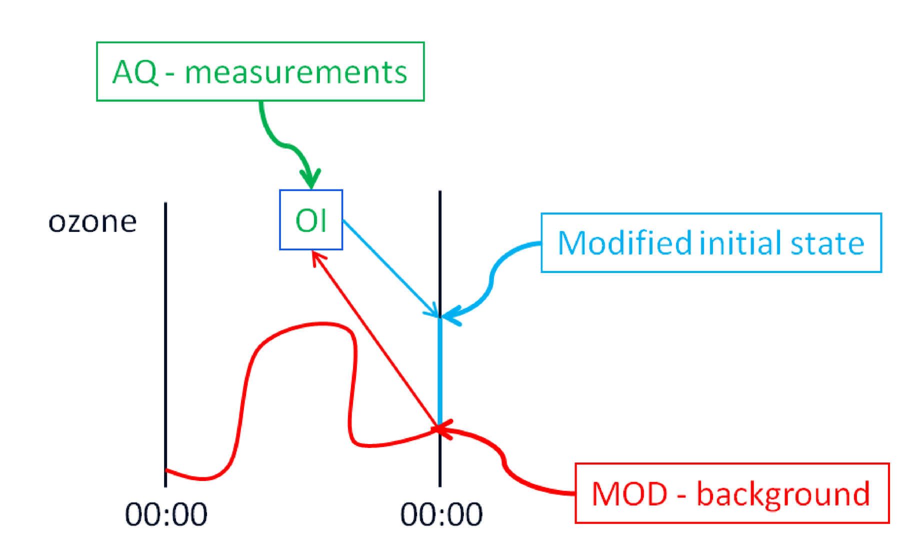


Fig. 3: Data assimilation cycle in AQA

Evaluation of the assimilation schemes

For the evaluation of the data assimilation scheme August 2009 was chosen. During this month the operational ozone forecasts conducted by the ZAMG over predicted the measurements for long time periods. Analysis showed that already the initial conditions used by the model in the morning were much higher than the concentrations which were observed at the stations of the Austrian Air Quality network.

The time series of model runs with and without data assimilation are compared in Figure 4 with measurements in ozone region 1. For most of the days in August 2009 the assimilation of the ozone measurements leads to a strong improvement of the model forecasts. Especially the daily mean values are predicted very well by the model runs using data assimilation (Fig. 4, left). The green line in Figure 4 (middle) shows that the modelled daily maximum ozone values using data assimilation stays at the upper edge of the grey shaded area, which indicates the highest measurements in O3 region 1.

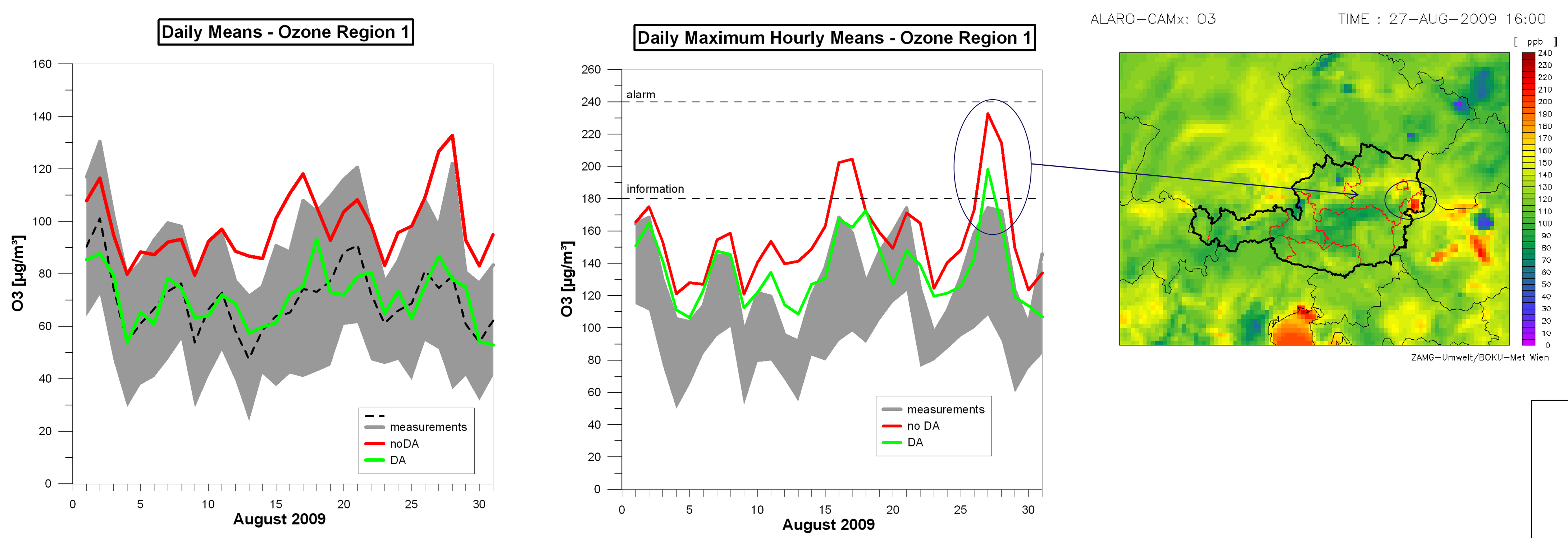


Fig. 4: Daily mean values (left) and daily hourly peak values (middle) during August 2009 in ozone region 1 (north-east Austria). Right: ground level ozone distribution on 27th of August at 4 pm.

The peak on 27th of August was investigated in more detail. On that day ozone concentrations between 190 and 200 µg/m³ (orange) were predicted by the model while the observations stayed below 160 µg/m³. The highest predicted values are located in Burgenland and reach values of up to 190-200 µg/m³ (orange). This peak is very local and actually only appears in one grid cell. The highest ozone values in other regions were predicted better by the model. For example: in Klosterneuburg (north of Vienna) the model forecast leads to concentrations between 150 and 160 µg/m³ (yellow) which is close to the highest observed ozone values of169 µg/m³ in that region.

Figure 5 shows that also in regions with complex terrain the model predictions are improved significantly when data assimilation is used. The average concentrations show a very good agreement with the measurements and also the predicted peak values lie close to the measurements on most of the considered days.

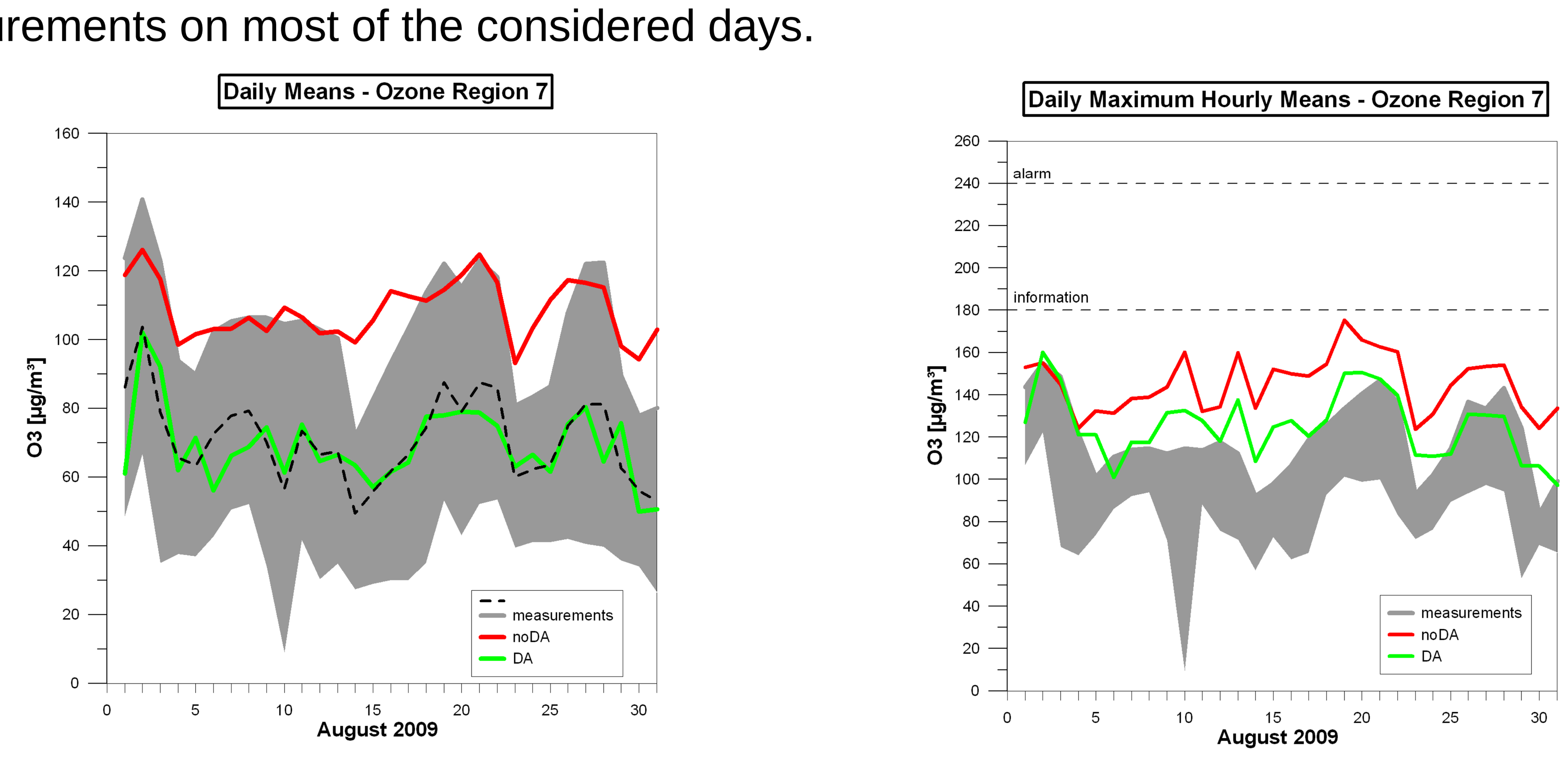


Fig. 5: Daily averages (left) and maximum daily hourly values (right) in August 2009 in ozone region 7 (Carinthia and East Tyrol).

FB vs. NMSE

Figure 6 shows the parable plots of the fractional bias (FB) and the normalized mean square error (NMSE) for different model runs and areas.

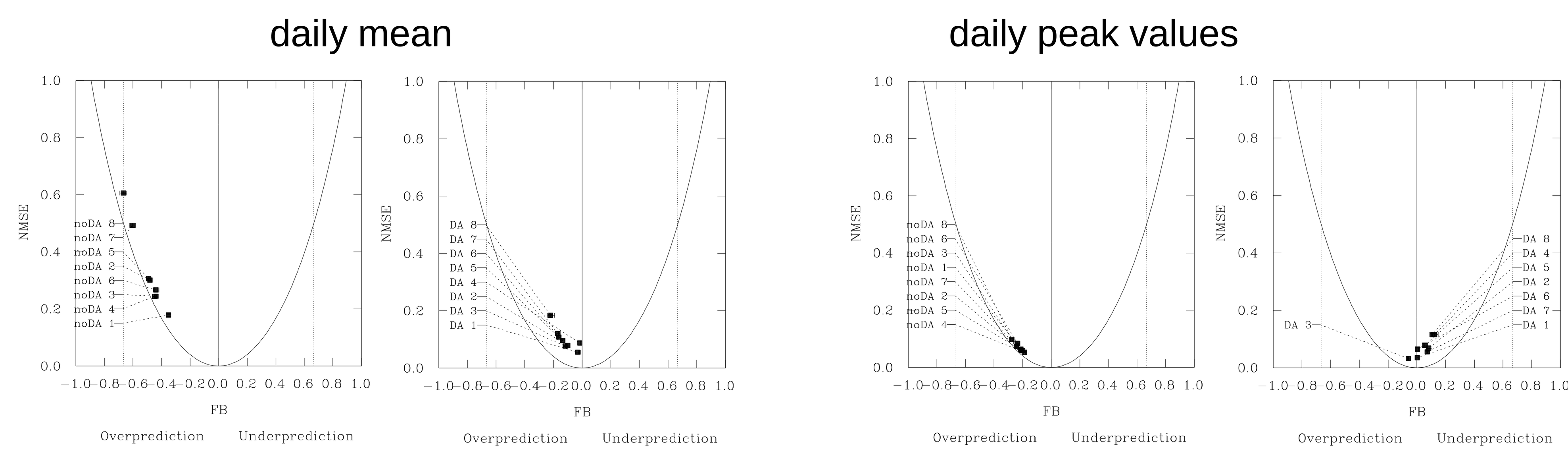


Fig. 6: NMSE vs. FB for different ozone regions for model runs with- and without data assimilation.

Considering the daily mean values the data assimilation leads to a strong reduction of the NMSE. Also the FB is lower than without including observational data. The improvement is weaker when the daily maximum values are considered. Also without data assimilation the NMSE lies below 0.2. The FB is shifted towards positive values when data assimilation is implemented.

Dynamic boundary conditions obtained from MACC

For many meteorological conditions the boundary concentrations can have an influence on the concentration values in the centre of the domain. Alternatively to the monthly average concentrations values obtained from long year model simulations the (daily) predicted concentration values provided by larger scale models can be used.

GMES (Global Monitoring for Environment and Security) is the European Programme for the establishment of a European capacity for Earth Observation. MACC (Monitoring Atmospheric Composition and Climate) is the current pre-operational atmospheric service of the European GMES programme. In the frame of MACC forecasts of the distribution of key constituents for a few days ahead are provided via ECMWF and can be used as dynamic boundary conditions for AQA.

Comparison of model runs with AQA using monthly mean boundary conditions and dynamic MACC forecasts show that the boundaries can have an influence on the concentrations also in the middle of the domain and in this case it improves the forecasts slightly.

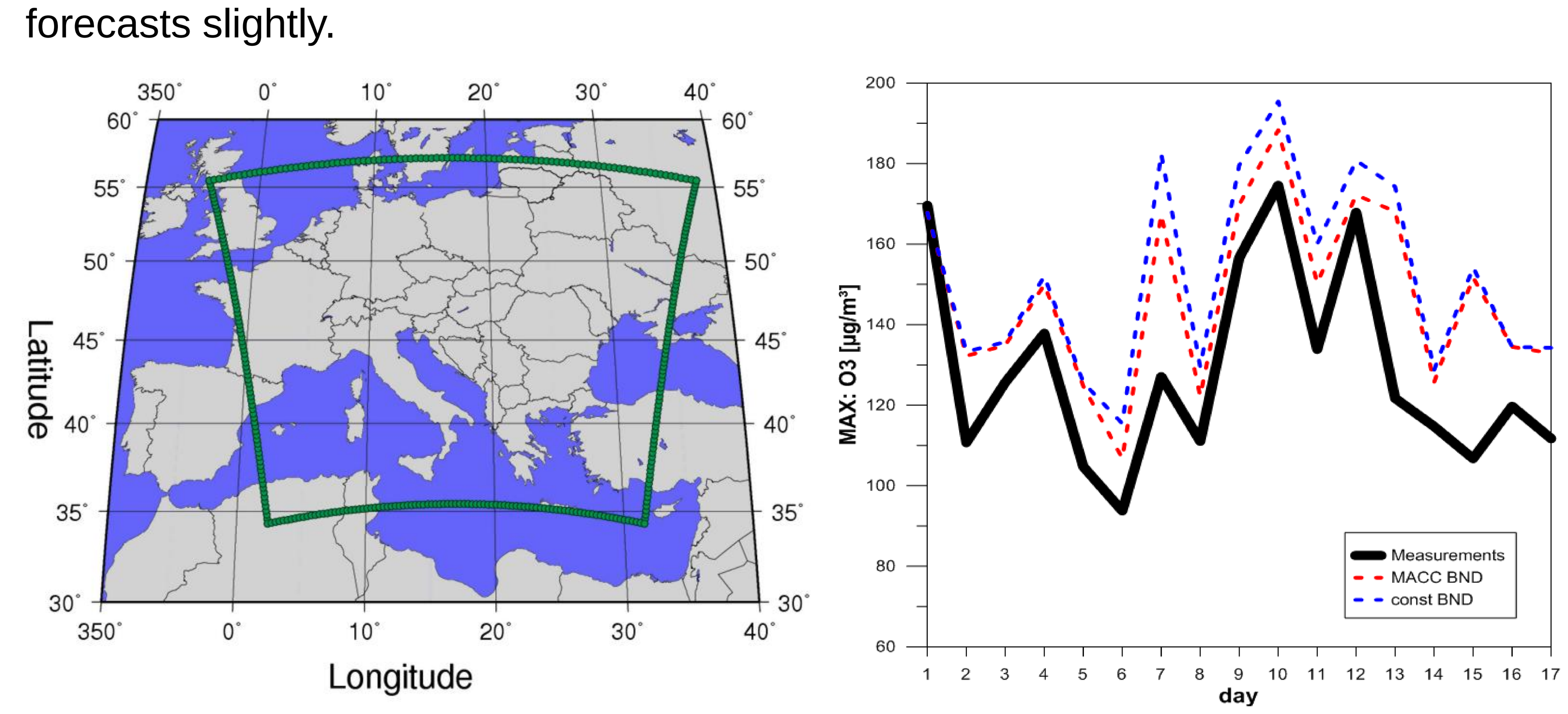


Fig. 7: Left: boundary conditions extracted from the MACC forecasts for the AQA domain. Right: time series of two different model runs compared to observations.

Conclusions

A data assimilation scheme has been implemented to improve the daily ozone forecasts of the ZAMG. Background fields obtained from model forecasts are combined with measurement data of the Austrian Air Quality network using optimum interpolation routines to obtain the best possible initial conditions. Investigations show that the initial concentrations values of ozone can have an influence on the predicted concentrations on the first few days. The assimilation scheme was evaluated for a selected summer episode in 2009 when the operational model forecasts over-predicted the measurements during many days. It is shown that when measurement data is assimilated the forecasts improve significantly also in complex terrain. Especially the daily averages show a very good agreement with the measurements using data assimilation. Also the prediction of the daily maximum hourly values show much better results using the new schemes. Next steps to further improve the model forecasts could be to include also ground measurements outside of Austria into the modeling system, and also to include information of the vertical concentration profiles e.g. using satellite measurements.

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