ABSTRACT

The effect of climate change and two different emissions scenarios on near-future (2026-2035) surface O\textsubscript{3} concentrations over Belgium is investigated with the regional air quality model AURORA at an unprecedented horizontal resolution of 3 km. The model is able to reproduce the spatial patterns and 10-year mean values of 34 observation stations. The results show that surface O\textsubscript{3} concentrations are expected to increase significantly over Belgium. However, a seasonal analysis reveals that the emission reductions pay off during peak episodes in summer, and the number of exceedance days is reduced.

KEY WORDS: Climate change, pollutant emissions, O\textsubscript{3} concentrations, regional air quality model, Belgium

1. INTRODUCTION

Air pollution results from a combination of emissions and weather conditions and therefore is sensitive to climate change. To assess this effect over Belgium, the Modelling Atmospheric Composition and Climate for the Belgian Territory (MACCBET) project is carried out. Within the framework of the project, a modelling experiment is set up in which a regional air quality model is driven with meteorological input from a regional climate model, applying a one-way nesting strategy. The study focuses on impacts in the near future (2026-2035), since policy makers indicated that this is more relevant to them than projections for a more distant future. The relevance of our results for local policy makers is further increased by applying an additional emission scenario that was designed by the Flemish administration. The work presented here will focus on near-surface O\textsubscript{3} concentrations.

The effect of climate and emission changes on O\textsubscript{3} concentrations has been the subject of several publications in international literature. Jacob and Winner (2009) reviewed multiple studies with global climate and air quality models and reported that summertime surface O\textsubscript{3} is expected to increase in polluted regions over the coming decades. In contrast, the higher water vapor in the future is expected to decrease the background O\textsubscript{3} in the troposphere. Kelly et al. (2012), using regional models over the USA, also found that climate change alone would lead to increased surface O\textsubscript{3} concentrations, especially in urban areas. However, the effect of emission changes was more dominant and resulted in decreased concentrations, except in very polluted high NO\textsubscript{x} areas where it leads to less O\textsubscript{3} titration and hence higher concentrations. The same effect is demonstrated by Hedegaard et al. (2012) in a study over Europe: O\textsubscript{3} concentration changes are dominated by expected emission reductions, which lead to increases over the Benelux, a very polluted area, where less titration will occur.

Our work builds on the previous research by applying several emission scenarios and going towards a horizontal model resolution of 3 km that is unprecedented for this kind of study.

2. NUMERICAL MODELS AND EXPERIMENT SETUP

The simulations in this study are performed with the regional-scale air quality model AURORA (Air quality modelling in Urban Regions using an Optimal Resolution Approach), a limited-area Eulerian chemistry transport model, developed at VITO and described in Van de Vel et al. (2009) and Lauwaet et al. (2012) and references therein. In the model setup, 6 emission classes are taken into account, including both gaseous and particle emissions. Large-scale pollutant concentrations, which are required to account for remote emission sources, are interpolated from output generated by the chemistry-transport model TM5 (Huijnen et al. 2010), as shown in Figure 1. Meteorological input for AURORA is provided by the regional climate model COSMO-CLM, the product of a joint effort from the Consortium for Small-scale Modelling (COSMO) and the Climate Limited-area Modelling Community (CLM-Community). A detailed description and full documentation of the
model is provided by Doms (2011). Boundary data for COSMO-CLM are provided by either the global climate model EC-Earth (Hazeleger et al. 2010; 2012) or the ERA-Interim analysis of ECMWF.

Figure 1: Schematic overview of the coupling between all atmospheric models.

This model setup is applied to simulate a 10 year reference period (2000-2009), driven with meteorological data from the EC-Earth base run, and a period in the near future (2026-2035), driven with EC-Earth model results for IPCC-scenario RCP (Representative Concentration Pathway) 4.5 (Van Vuuren et al. 2011). Consequently, future emissions from anthropogenic sources and biomass burning for the air quality models are also based on the RCP4.5 dataset. To increase the relevance of our results for local policy makers, the 2026-2035 period is also simulated by AURORA with a second emission scenario (called MIRA), that was designed by the Flemish administration. An overview of the applied emission and climate changes towards the near future is provided in Table 1.

<table>
<thead>
<tr>
<th>Component</th>
<th>RCP4.5 Europe</th>
<th>RCP4.5 Belgium</th>
<th>MIRA Europe</th>
<th>MIRA Belgium</th>
<th>Variable</th>
</tr>
</thead>
<tbody>
<tr>
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<td>-70%</td>
<td>-45%</td>
<td>-25%</td>
<td>T2m</td>
</tr>
<tr>
<td>SOx</td>
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<td>-75%</td>
<td>-40%</td>
<td>-65%</td>
<td>Rain</td>
</tr>
<tr>
<td>NMVOC</td>
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<td>-55%</td>
<td>-40%</td>
<td>-35%</td>
<td>BLH</td>
</tr>
<tr>
<td>PM</td>
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<td>-85%</td>
<td>-10%</td>
<td>-25%</td>
<td>qv</td>
</tr>
<tr>
<td>NH3</td>
<td>-6%</td>
<td>+15%</td>
<td>-30%</td>
<td>-25%</td>
<td>Wind</td>
</tr>
</tbody>
</table>

Table 1: Overview of the applied emission and climate changes (over Belgium) between the present day (2000-2009) and the near future (2026-2035).

In order to evaluate the model results, 34 observation stations from the AirBase data archive (Mol et al. 2011) are used. The locations of the stations within the 3 km model domain are shown in Figure 2. Given this model resolution, we only selected background stations, excluding traffic and industrial stations as these are generally not representative at the scale of a 3 km model grid cell.

Figure 2: Overview of the 3 km model domain and the location of major cities (white squares) and observation stations (white triangles). The location of station ‘Lanaken’, used in Figure 5, is indicated with a red triangle.
3. RESULTS AND DISCUSSION

Since the EC-Earth simulations result in a climate change representation, it is not possible to validate the modelled time series of the \( \text{O}_3 \) concentrations. However, the 10-year mean values for the present day period should be very close to the measurements. Figure 3 shows that the AURORA model is able to reproduce the observed concentrations with a high spatial correlation, although the model has a slight positive bias, especially at the most polluted stations.

The impact of both climate and emission changes on near-future surface \( \text{O}_3 \) concentrations is shown in Figure 4. Both emission scenarios show an increase in the concentrations up to 30% of present day values, especially in the areas with the highest \( \text{NO}_x \) emissions. The increase is slightly higher for the MIRA scenario, probably due to the fact that NMVOC emissions are less reduced in this scenario compared to RCP4.5. Clearly, the emission changes and the consequent negative effect on \( \text{O}_3 \) titration dominate these results, in agreement with the conclusions of related international research (Hedegaard et al. 2012; Kelly et al. 2012).

However, this overall picture hides some interesting underlying trends. Figure 5 shows a deeper analysis that is performed for the station ‘Lanaken’ (see Figure 2) and where the mean daily cycles are plotted per season. The comparison with the observations provides a further evaluation of the model performance. The results show that the \( \text{O}_3 \) increases are largest at night time and during the winter period, when the titration effect plays its role. During daytime in summer, the overall increase is very small. When we consider the peak episodes (plotted as the 95th percentile), we even see a decrease in the concentrations as the reduced emissions limit the \( \text{O}_3 \) formation during these episodes. This also shows in the number of days where the 8-hour maximum threshold of 120 \( \mu \text{g m}^{-3} \) is exceeded: these are reduced with 25% for both scenarios. Thus, although the overall numbers show a significant increase in surface \( \text{O}_3 \) concentrations, the emission reductions are able to suppress the number of exceedances.

![](image-url)

Figure 3: Evaluation of the 10-year mean (2000-2009) \( \text{O}_3 \) values for all observation stations.
Figure 4: Mean difference maps between the present day (2000-2009) and the near future (2026-2035) for the RCP4.5 scenario (left) and the MIRA-Europe scenario (right).

Figure 5: Mean daily cycle of O₃ concentrations at station ‘Lanaken’ per season. In summer, also the 95th percentile is plotted (dotted lines).
4. PRELIMINARY CONCLUSIONS AND OUTLOOK

In this study, the effect of climate change and two different emissions scenarios on near-future (2026-2035) surface O₃ concentrations over Belgium is investigated with the regional air quality model AURORA, driven by the regional climate model COSMO-CLM, at an unprecedented horizontal resolution of 3 km. The model was able to reproduce the spatial patterns and 10-year mean values of 34 observation stations. The results showed that surface O₃ concentrations are expected to increase significantly over Belgium, due to less O₃ titration by lower NOₓ emissions. However, a seasonal analysis revealed that the emission reductions pay off during peak episodes in summer, and the number of exceedance days is reduced.

During the coming month, these results will be further elaborated and the effect of climate change alone will be investigated.

REFERENCES


