Case studies with WRF-Chem: Scale interactions in ozone formation

Ø. Hodnebrog, F. Stordal, and T. K. Berntsen
Department of Geosciences, University of Oslo,
P.B. 1022 Blindern, N-0315 Oslo, Norway

1 Introduction

Distributions and changes in tropospheric ozone on a global scale are normally calculated with rather coarse resolution Chemistry-Transport Models (CTM). However, a substantial part of the chemistry affecting production of ozone takes place in polluted regions on scales well below the resolution of global CTMs. This introduces errors as the formation of ozone from ozone precursors is nonlinear. In order to quantify such inaccuracies we have used the WRF (Weather Research and Forecasting) model with RADM2 chemistry, and performed simulations with various emission resolutions.

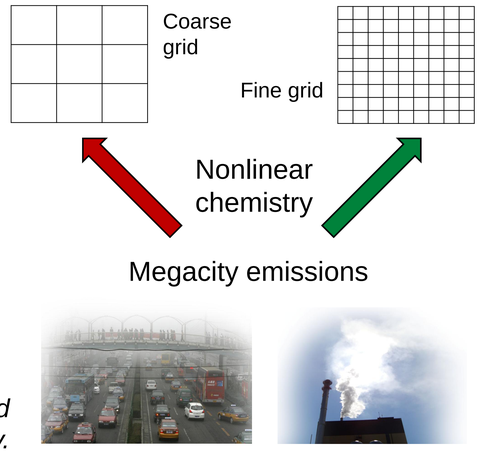

Figure 1. *The scale of which the megacity emissions are implemented in a Eulerian model could affect the nonlinear ozone chemistry.*

2 Emissions and setup

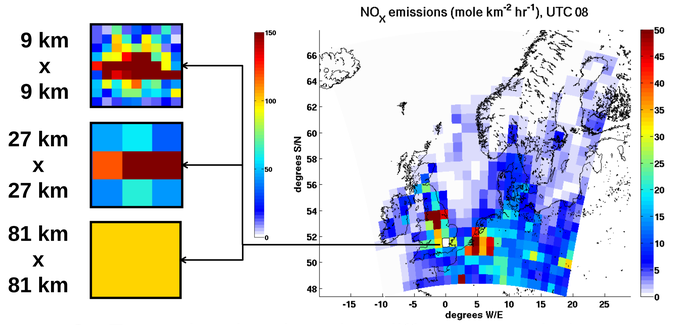

Figure 2. *Example showing the different resolutions used for megacity NO_X emissions (mole km^{-2} hr^{-1}) at 08 UTC in the London simulations.*

- Two 3-day time periods were simulated for each of the megacities / hot spot regions **London**, **Cairo** and **Ruhr**.
- Model resolution has been kept constant at 9 km x 9 km, while the emission resolution of ozone precursors (CO, NO_X, VOC) was changed in the simulations.
- London emissions were used over the location of Cairo in order to investigate the effect of different meteorological conditions and background chemistry.

Table 1. *Emission inventories used in the simulations.*

Inventory	Resolution	Coverage
NAEI	1 km x 1 km	United Kingdom
LANUV	1 km x 1 km	North Rhine Westphalia
EMEP/INERIS	0.1° x 0.1°	Europe (approx.)
RETRO	0.5° x 0.5°	Global

3 Ozone changes

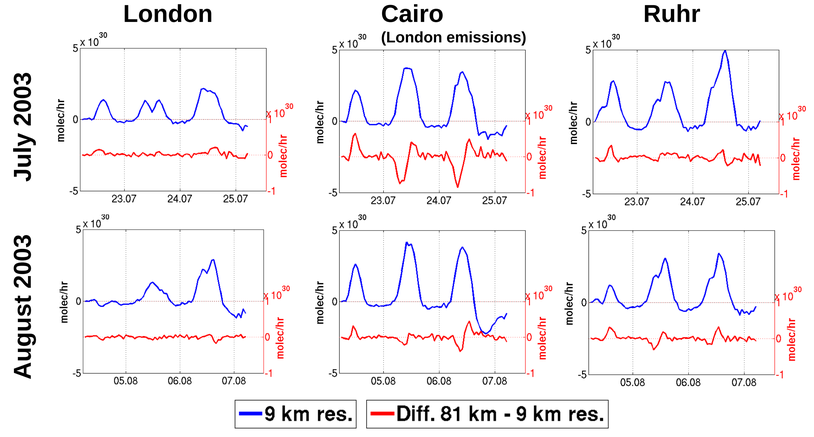

Figure 3. *Hourly change in ΔO_3 (molec/hr) caused by megacity / hot spot emissions, integrated over the whole domain for the 9 km emission resolution (blue) and as differences between 81 km and 9 km (red).*

	London		Cairo (London emissions)		Ruhr	
Resolution	*Jul*	*Aug*	*Jul*	*Aug*	*Jul*	*Aug*
81 km x 81 km	+5.7 %	-1.9 %	-1.6 %	+0.6 %	+0.5 %	+0.1 %
27 km x 27 km	+2.5 %	-0.8 %	-2.3 %	-1.1 %	+0.4 %	+0.7 %

Table 2. *Difference in impact of megacity / hot spot emissions on O_3 at the end of each 3-day period, relative to fine scale results (9 km x 9 km).*

4 Chemistry nonlinearities

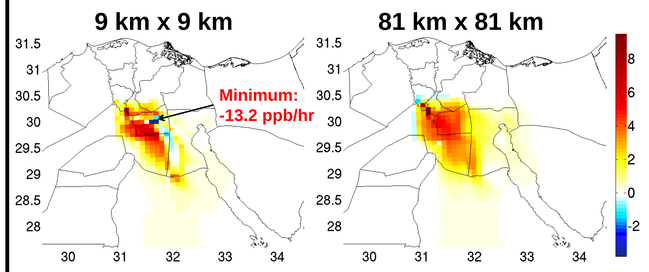

Figure 4. *Chemical prod / loss of ΔO_3 (ppbv/hr) near the surface in Cairo (using London emissions) with 9 km x 9 km (left) and 81 km x 81 km (right) resolution of emission fields on July 23, 2003 at 12-13UTC.*

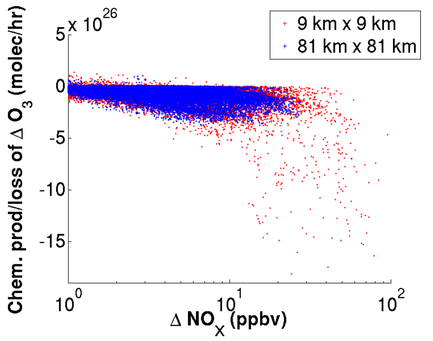

Figure 5. *Correlation of ΔNO_X (ppbv) with the chemical prod / loss of ΔO_3 (molec/hr) near the surface during the 3-day July 2003 period over London.*

5 Key findings

- Chemical nonlinearities are present (Figure 4 and 5), showing a lack of ozone titration in the core of the plume when coarse emissions are used.
- One case (London, July 2003) gives an overestimation of net ozone from the megacity of 5.7 % when comparing 81 km x 81 km with 9 km x 9 km (Table 2) emission resolutions. Corresponding values for the five other cases are less than 2 % and variable in sign.
- Results for Cairo are quite different from London results, although the same emissions have been used (Figure 3 and Table 2). This indicates the importance of meteorological conditions and background chemistry.
- Net ozone differences are less pronounced for Ruhr (Figure 3 and Table 2). This could be a result of the more homogenously distributed emissions compared to London.
- In general, we find that differences in net ozone are relatively small at these scales. However, changes in the resolution of the meteorology is not studied here and could give larger effects.

ACKNOWLEDGEMENTS
The research leading to these results has received funding from the European Union's Seventh Framework Programme (FP7/2007-2013) under Grant Agreement no. 212095. The authors would like to thank Landesamt für Natur, Umwelt und Verbraucherschutz NRW (LANUV) for providing emission data for the Ruhr area.