Developments in dispersion modelling over different spatial scales

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Motivation

- Why nest a local model within a regional model?

Model feature	Model	
	Regional (eg grid based)	**Local (eg Gaussian plume)**
Domain extent	Country (few 1000 km)	City (50km)
Meteorology	Spatially and temporally varying from meso scale models	Usually spatially homogeneous
Dispersion in low wind speed conditions	Models stagnated flows correctly	Limited modelling of stagnated flows
Deposition and chemical processes	Reactions over large spatial and temporal scales	Simplified reactions over short-time scales
Source resolution	Low	High
Validity	Background receptors	Background, roadside and kerbside receptors

Motivation

- Why nest a local model within a regional model?
- What are the advantages of a **nested model**?

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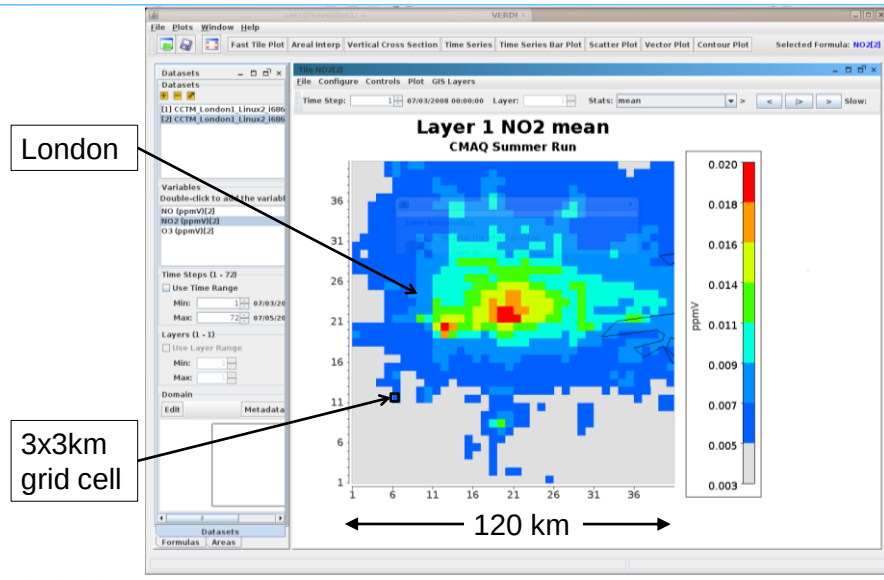
CMAQ overview

- **C**ommunity **M**ultiscale **A**ir **Q**uality modelling system
- Originally developed by the US Environmental Protection Agency (EPA), now supported by CMAS (Community Modelling and Analysis System)
- Open-source model that runs on Unix operating systems, with a command line and script-based user interface
- Grid-based (Eulerian) model
- Highest resolution typically 1-3km
- Meteorology from MM5 or WRF meso-scale models
- Emissions processing via SMOKE (US) or gridded data directly into I/O Applications Programming Interface (API) format
- Data visualisation in VERDI (Visualisation Environment for Rich Data Interpretation)

CMAQ output concentration data shown in VERDI



CMAQ/ADMS-Urban nesting system

- **Aim:** to nest local model in regional model without double counting emissions i.e.:

Concentration within nested domain	=	Regional modelling of emissions	-	Gridded locally modelled emissions (ΔT)	+	Explicit locally modelled emissions (ΔT)

ΔT is the time taken to mix the explicitly defined emissions to produce a concentration field that varies spatially on the same scale as the regional model

ΔT varies with meteorology

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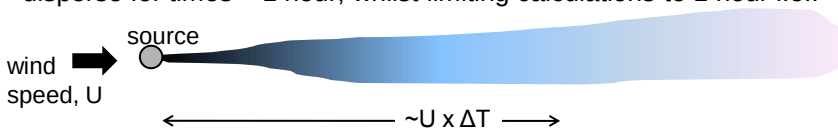

- Assumption valid if variation in meteorology and emissions relatively slow from hour to hour.

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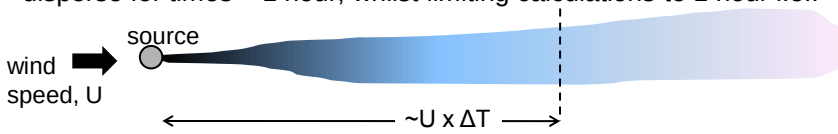
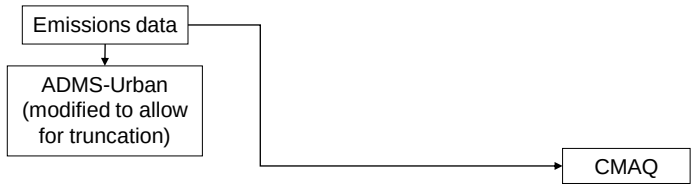


- Assumption valid if variation in meteorology and emissions relatively slow from hour to hour.
- When nesting ADMS-Urban in a regional model, ensure that the locally modelled emissions (gridded and explicit) are **truncated** (- - -) at the correct time.

CMAQ/ADMS-Urban nesting system

Emissions data

CMAQ/ADMS-Urban nesting system



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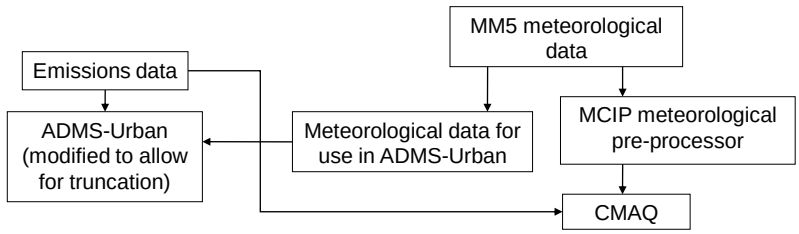

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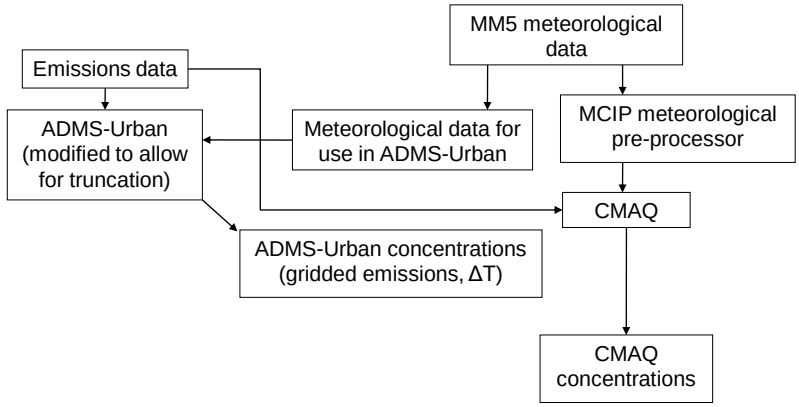

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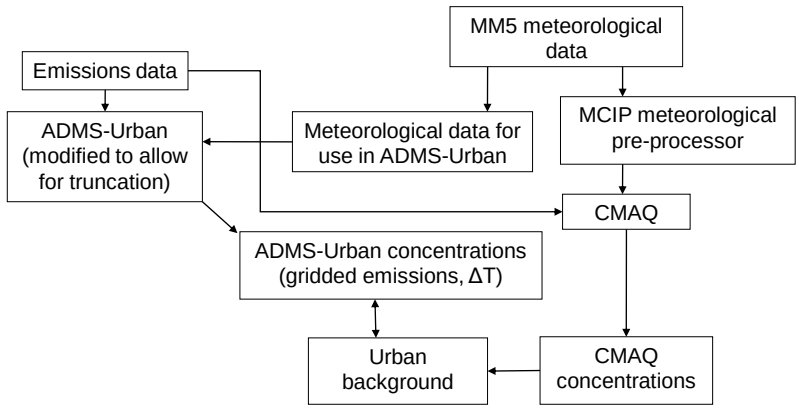

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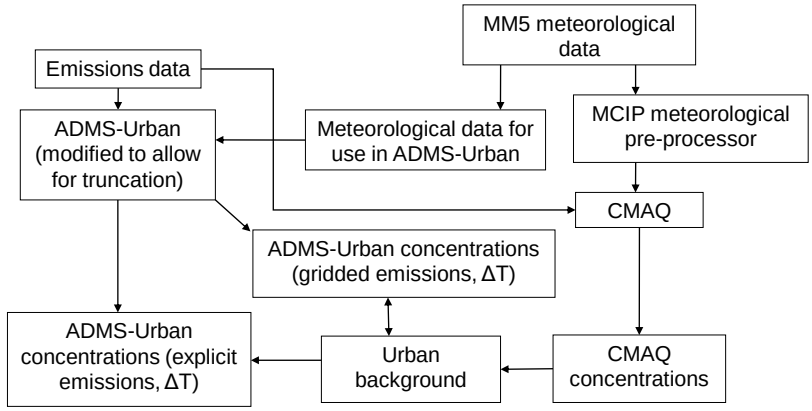

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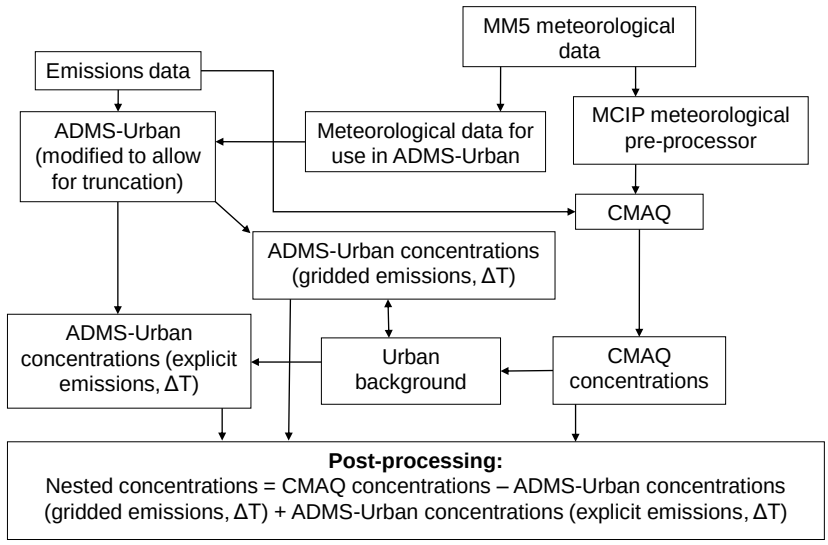
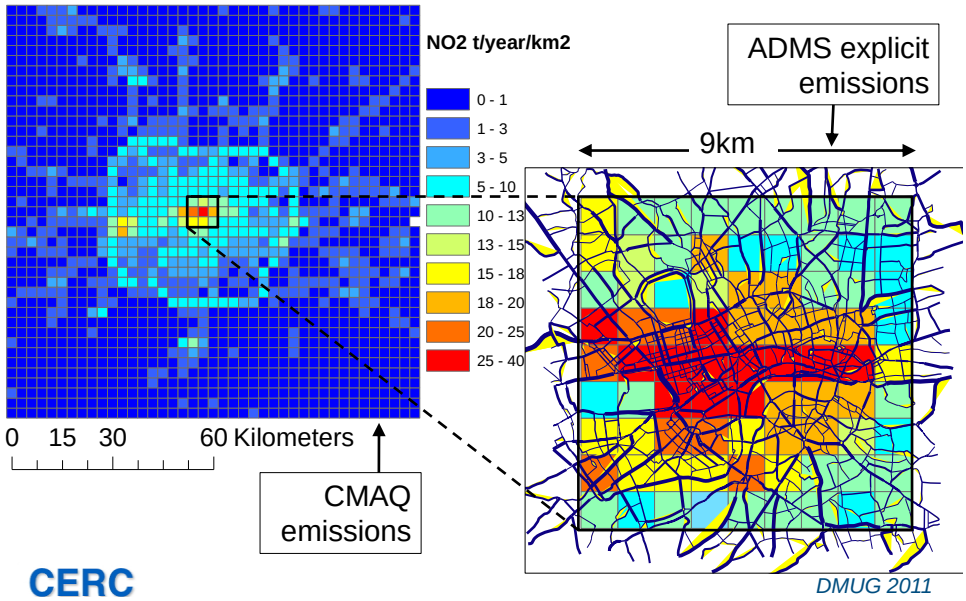


Preliminary modelling
Model set up

- **Simplified model set up**

- Domain:
  - Regional model : south east England
  - Local model : ~ congestion charging zone in central London
- Emissions:
  - London Atmospheric Emissions Inventory (detailed) and UK National Atmospheric Emissions Inventory (1 km^2 grid)
  - Only emissions of NO_x, NO_2 and ozone
  - Emissions from large point sources neglected
- Meteorology
  - Output from the meso-scale model MM5
  - 2 x 5 day periods (summer, winter)

Preliminary modelling
Model set up: NO_2 emissions



Preliminary modelling
Model set up

- **Simplified model set up**

- Regional model:
  - Domain 120 km by 120 km, centred on nested domain
  - Emissions were aggregated onto 3 by 3 km^2 grid cells
  - All emissions released within the lowest layer of CMAQ vertical grid
  - Simplified initial and boundary conditions
  - CB-05 version 5 aerosol mechanism and aqueous chemistry
- Local model
  - Domain 9 km by 9 km
  - Emissions from all major roads modelled explicitly
  - Source-receptor travel time/mixing time ΔT limited to 2 hours

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Model results

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  - All recorded NO_x and NO_2 concentrations
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  - Classified according to location: kerbside, roadside and urban background

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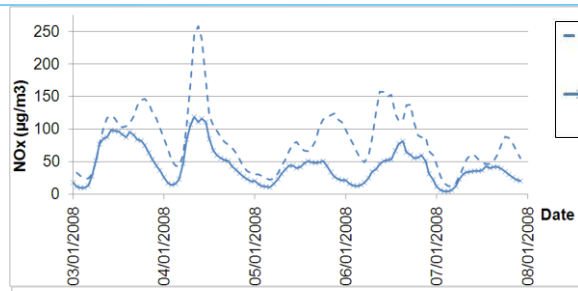
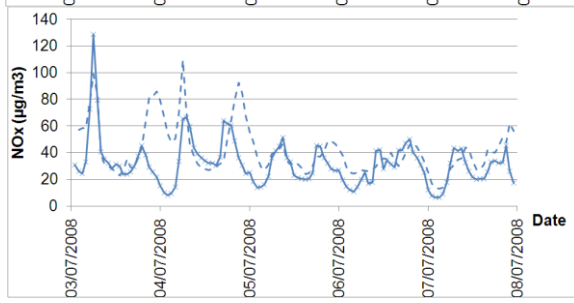
Preliminary modelling
Model results: validity of nesting

Winter



Summer



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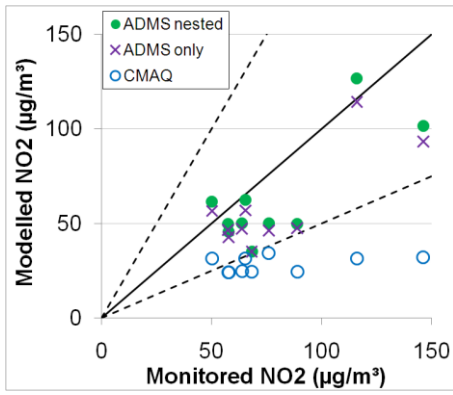
- Model results at receptors:
  - ADMS-Urban nested within CMAQ
  - CMAQ only
  - ADMS-Urban only

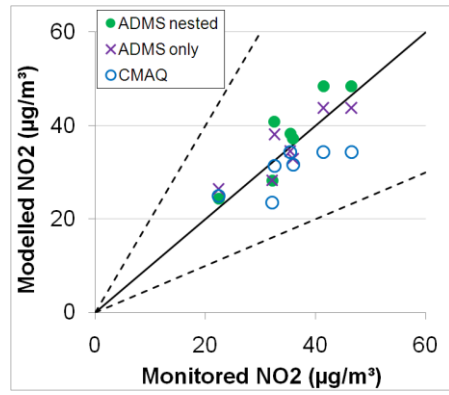
Preliminary modelling

Model results: receptors – NO_2

Roadside and Kerbside



Background

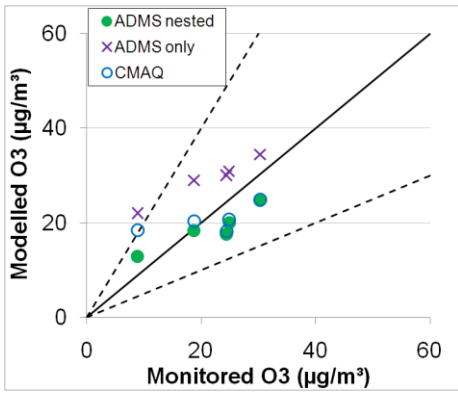


(Summer)

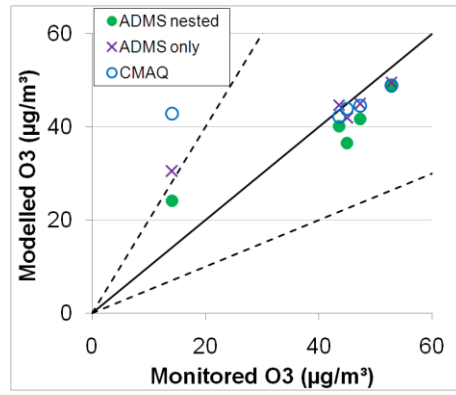
Preliminary modelling

Model results: receptors – O_3

Winter



Summer



(All sites)

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- Contour output:
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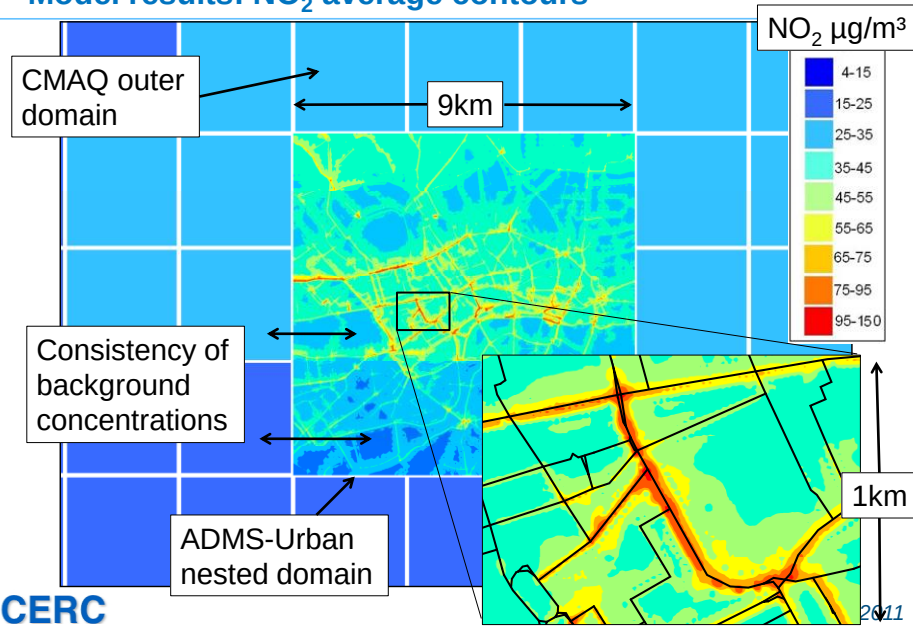
Preliminary modelling
Model results: NO_2 average contours



Summary

- Consistent methodology for nesting local model within a regional model
- Preliminary model results encouraging, despite simplifications
- This approach allows for modelling of:
  - chemical reactions over large and small temporal and spatial scales
  - spatially varying meteorology
  - low wind conditions
  - local modelling (street canyons, noise barriers, cuttings etc)
- Model validation at *all* sites: background, roadside and kerbside

Future work

- Nesting in other regional models, eg. EMEP4UK for Defra model inter-comparison study (collaboration with CEH)
- Greater integration and automation of nesting system
- Inclusion of elevated point sources
- Extension to model aerosols (particulates)
- Improved boundary and initial conditions for regional model
- Larger regional modelling domain
- Multiple nesting levels in regional modelling

Any questions?