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Micro-scale AQ modelling using GRAL and RapidAir

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CT4 Micro-scale AQ modelling

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Model approach

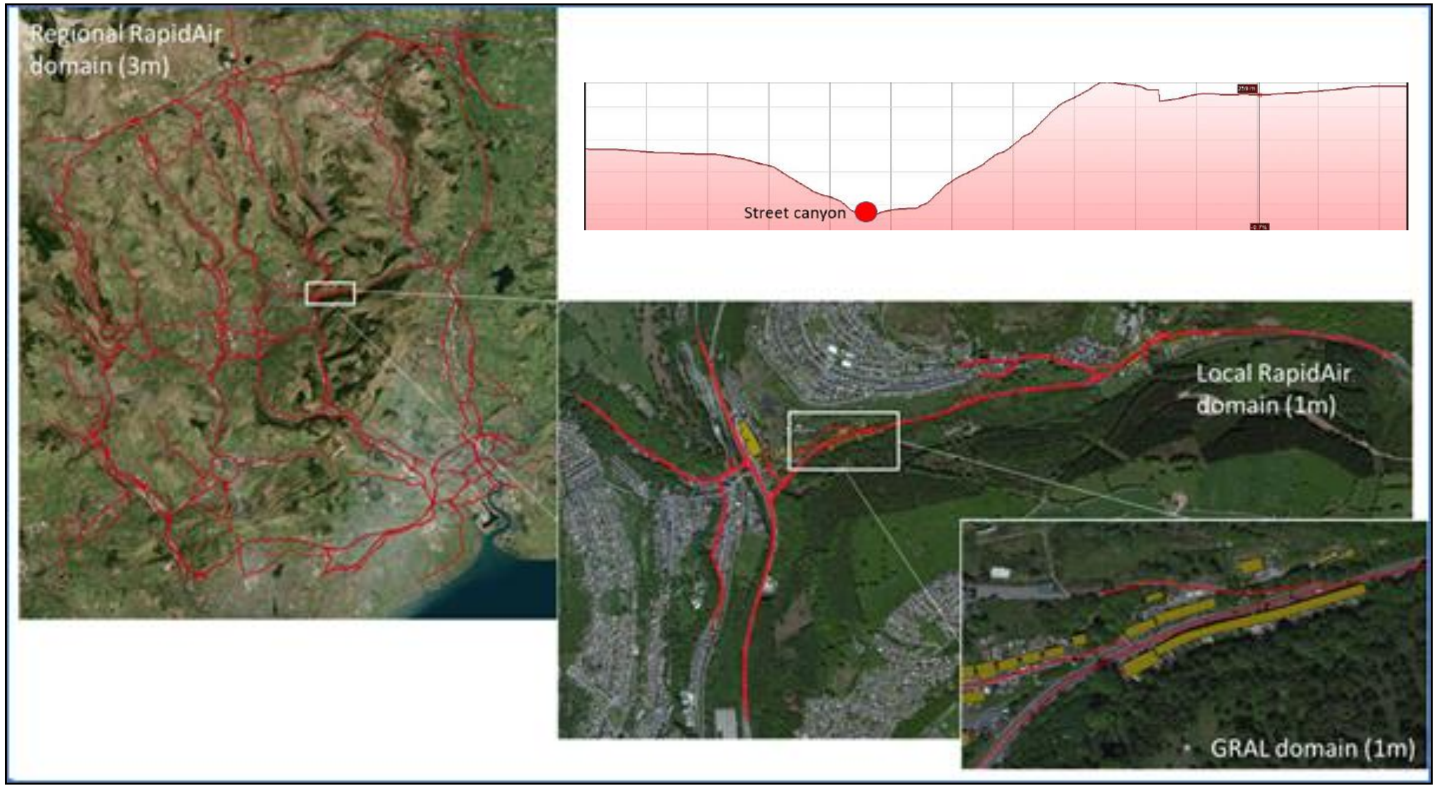
- Micro-scale (1m) modelling can be used to assess compliance with AAQD.
  - Trade off between model detail, domain size/resolution and model run times.
- Steady-state models in combination with street canyon model are, in the majority of our experience suitable to determine compliance. The exception being complex terrain where more complex dispersion treatment is required.

<u>Project example</u>:

- UK street in rural area with NO_2 annual mean ~70 ug/m^3
- Unusually high emissions + topography = compliance problem

Aims

- Harness traffic microsimulation outputs without losing information
- Create AQ models supporting local compliance assessment and regional implication of local traffic interventions
  - RapidAir (based on AERMOD)
  - GRAL (Graz Lagrangian model)



Model setup

Inputs

Shapefile of data from microsimulation transport model for hourly periods
Real-world emission factors to produce NOx emissions for each link
Hourly surface and upper air meteorology measurements
Shapefile of building footprints and heights

RapidAir

Based on AERMOD
Model resolution: 1-3 m resolution
Domain size: $5 km^2$ – $900 km^2$
Run time: hours

- Meteorology processed by AERMET to required formats
- AERMOD used to generate dispersion kernels for idealised traffic sources
  - Kernels produced for an average for each hourly period
  - Convolution used to calculate concentrations
- AEOLIUS model used to calculate recirculation effects within street canyons

GRAL

Lagrangian model
Model resolution: 1 m
Domain size: $0.05 km^2$
Run time: days

- 3D grids of meteorology and stability generated for each hour (e.g. using GRAMM)
- GRAL used to calculate dispersion for idealised source
  - Particle tracking within a 3D wind field
  - Flows around obstacles, buildings and terrain resolved each hour
  - Outputs scaled by emissions to produce concentrations

Outputs

Gridded hourly concentrations
Post-processing gridded annual concentrations

Simulations needed to retrieve annual statistics

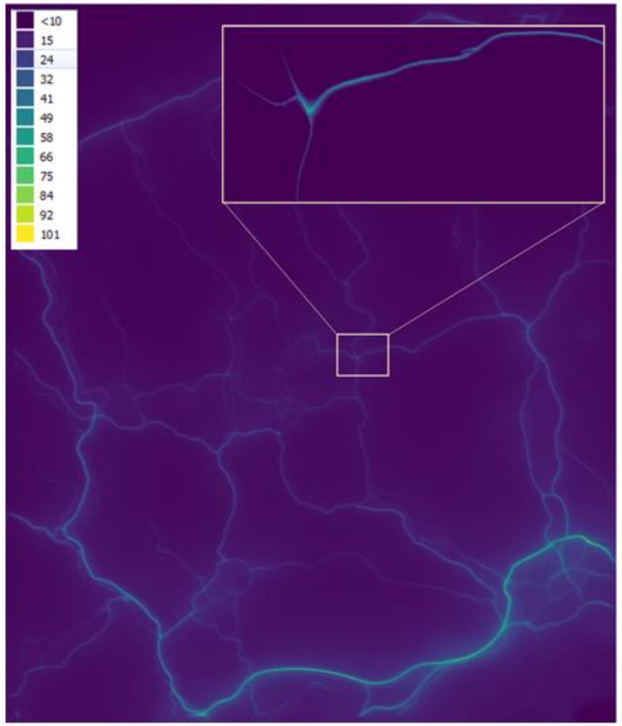
- **RapidAir**
- The model takes diurnal patterns in traffic into account within the kernel from the hourly traffic microsimulation data*
- Hourly average gridded NOx concentrations produced
- These can be converted to NO2 using polynomial relationships e.g. derived from Defra NOx to NO2 calculator (UK specific)
  - Hourly grids can be combined to produce annual average concentrations for assessment of AAQD
- 24 (hourly) simulations can be used to establish AAQD compliance for each scenario

- **GRAL**
- Emissions patterns are determined from the hourly traffic data*, and are retained through to the hourly modelling
- We used grouping function in GRAL to model each road link separately for each hour as an idealised source to create an emissions database
  - 42 links, 24 hours = 1008 GRAL simulations
- Each link then looked up and scaled according to real emissions for each hour
  - This very complex and unmanageable for a human – we used python to reproducibly control the modelling process

* Resolved (temporal and spatial) traffic data is required for microscale modelling - typically the most detailed resolution is hourly

Procedure for retrieving annual indicators 1

- **RapidAir**
- Gridded hourly outputs from RapidAir can be combined to produce gridded annual average concentrations. This means concentrations can be sampled anywhere in the domain
- Concentrations should be sampled at monitoring locations for model verification
- For assessing compliance with AAQD, receptors can be generated following siting criteria from AAQD:
  - 4 m from kerb
  - 2 m height
  - not within 25 m of a junction
  - representative of 100 m stretch along all road links in the model domain



- By modelling a larger domain, any detrimental impacts of measures e.g. displacement of vehicles in response to a tested measure, will be captured

Procedure for retrieving annual indicators 2

- **GRAL**
- Concentration grids for each hour and each source are combined to produce annual average concentrations
  - This process relied on python controllers to perform combinations to avoid errors, and reduce time

Calculate emissions and compile emission factor library

Uphill or not?

Inside Clean Air Zone?

What hour is it?

Lookup correct emission rate from library for specifics of the link activity, time and setting

Match emission rate to the road by the link ID code

Match to GRAL dispersion grid for that link/hour/scenario

Weight GRAL grid by ratio of actual Vs idealised emissions

Compile > 300 GRAL results to one 'map'

Repeat for all scenarios/years

Automate extraction of receptor results

Validate model and scale results

Gridded concentration outputs from GRAL mean concentrations can be sampled anywhere within the domain including the at siting criteria outlined on previous slide or other locations of relevant exposure such as house facades in this example

Evaluation

All air quality models are verified against measurement data collected within the study area e.g. passive measurements or automatic samplers

RapidAir

- For this study RapidAir model RMSE 5.9 ug/m^3 (n=16)
  - This highlights the steady-state model struggles to refine the complex dispersion conditions in the model domain
- The RapidAir model has been approved for use in city-scale Clean Air Zone assessments in the UK by Defra.
  - Typical RMSE for city-scale RapidAir model 4 ug/m^3 NO_2
- RapidAir allows fast testing of mitigation scenarios and can captures any wider impacts e.g. traffic displacement of as a result of mitigation scenarios

GRAL

- GRAL model RMSE = 3.9 ug/m^3 (n = 16)
- Note: in this work we carried out a sensitivity test removing a large tree in the study domain – this showed no significant impact on concentrations
- This small domain (0.05 km^2) was computationally demanding, produced large volumes of data which, without python controllers, would have been unmanageable.
  - The application of this model for a larger domain would be challenging
- The small model domains allow detailed, robust testing of local mitigation schemes, however cannot model regional displacement as observed in this modelling study for example

- In the majority of cases the level of detail provided by the GRAL model is not necessary, and greater focus should be placed on assessment of city-scale concentrations.
- If city-scale measurements or model results suggested complex dispersion conditions then microscale modelling could be undertaken to fully understand pollution in the location in question