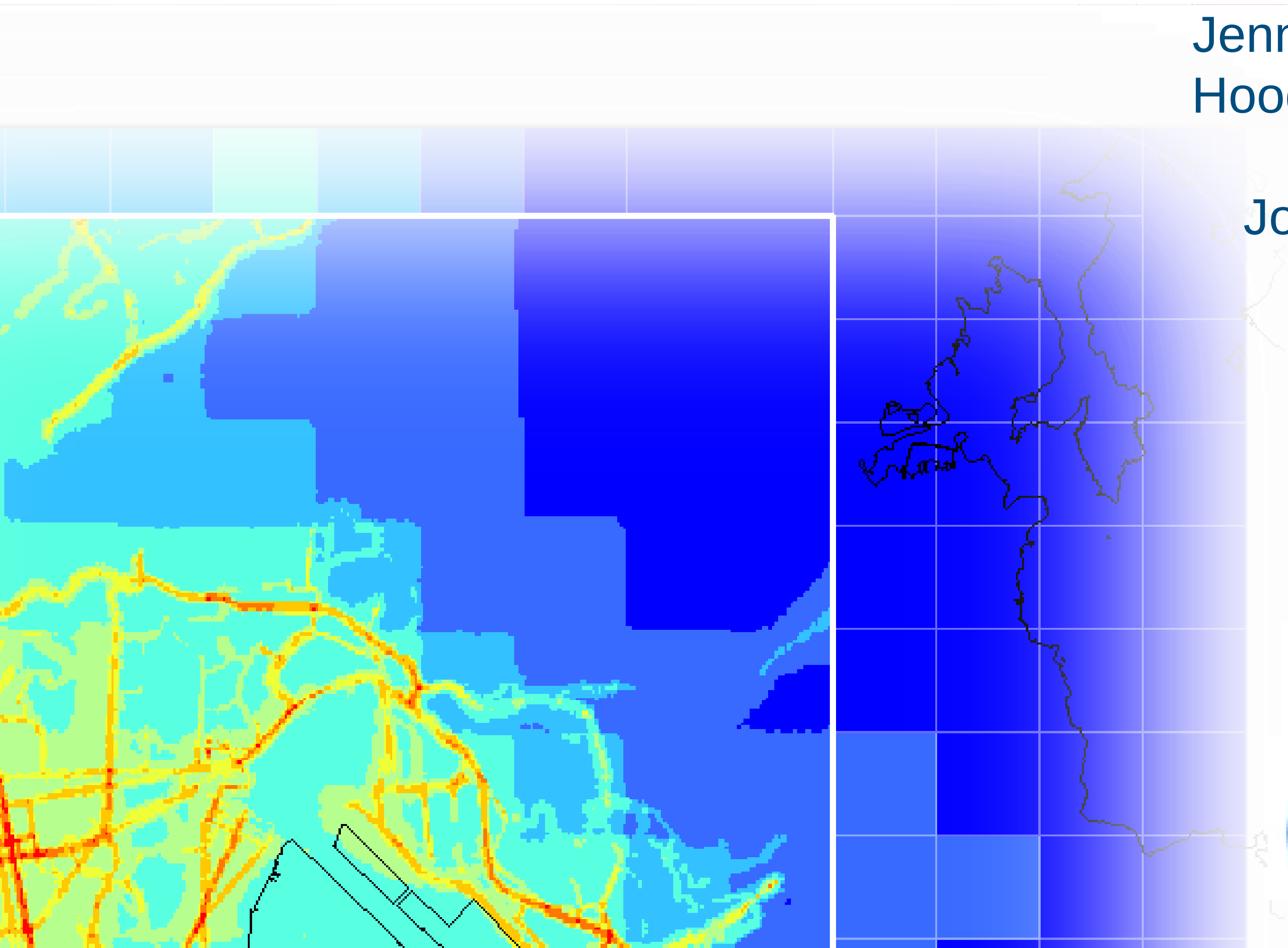
The Development and Evaluation of an Automated System for Nesting ADMS-Urban in Regional Photochemical Models



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Contents

- Introduction
- Nesting concept
- System implementation
- Example use of system:
  - Input data
  - System configuration
  - Run times
  - Validation methodology
  - Results
- Conclusions

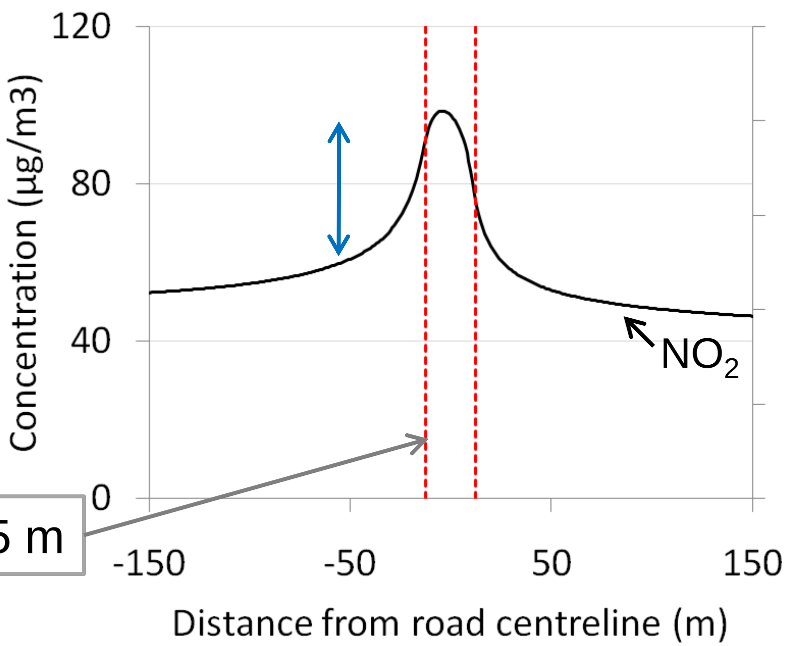
Introduction

- Regional **meteorological** models represent complex flow variations over large spatial scales
- Regional **photochemical** models represent complex chemistry and dispersion processes over large spatial scales
- Regional models are increasingly being required to run at high resolution to perform, e.g. pollutant exposure assessments
- Concentrations close to roads within urban areas vary significantly over tens of metres

Variation:
➢ Over 30 µg/m³ NO_2 within 50 m

Heavily trafficked road, no canyon

Road width 25 m



Introduction

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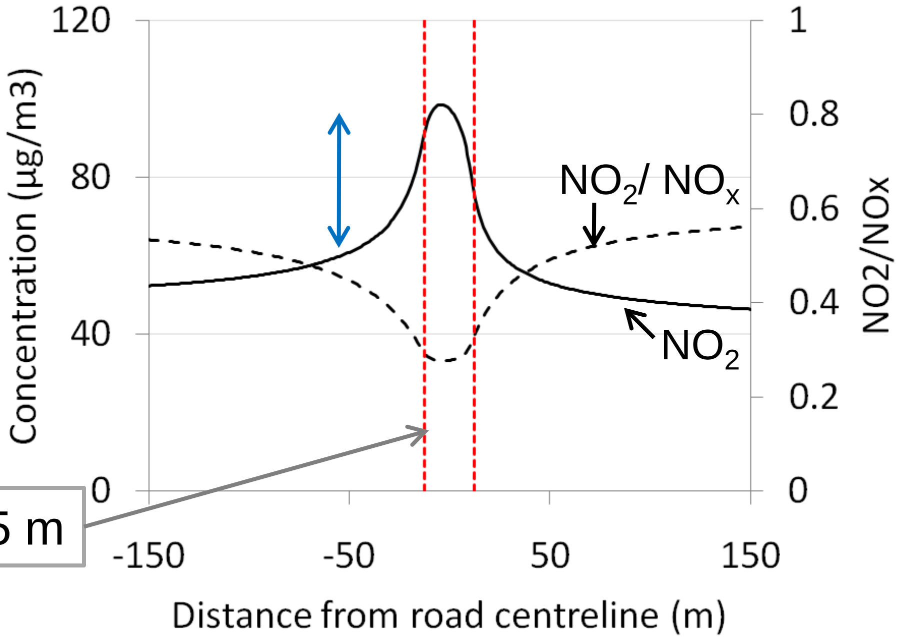
Variation:
- ➢ Over 30 µg/m³ NO_2 within 50 m
- ➢ Variation due to dispersion and chemistry

Heavily trafficked road, no canyon

Road width 25 m



Introduction

- Regional **meteorological** models represent complex flow variations over large spatial scales
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- Regional models are increasingly being required to run at high resolution to perform, e.g. pollutant exposure assessments
- Concentrations close to roads within urban areas vary significantly over tens of metres
- Issues with running regional models at high resolution include:
  - Difficult to include explicit modelling of roads and near-source features, e.g. street canyons
  - Run times and data storage requirements become prohibitive
  - Some parameterisations within the model become invalid, in particular cloud parameterisations in WRF

Introduction

- What are the advantages of a nested system of models?

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**

Nesting concept

- The nesting concept introduced in Stocker *et al.* (2012):
  - Exploits the advantages of each model type
  - Avoids double counting emissions
- Briefly:
  - At short time scales, the local model resolves the high concentration gradients close to roads, and performs fast NO_x chemistry
  - For longer time scales, the regional model accurately represents pollutant transport and complex chemical processes
  - Distinguish between the models using a ‘mixing time’, ΔT, defined as the time required for the pollutants to become uniformly mixed over the scale of the regional model grid

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

Nesting concept

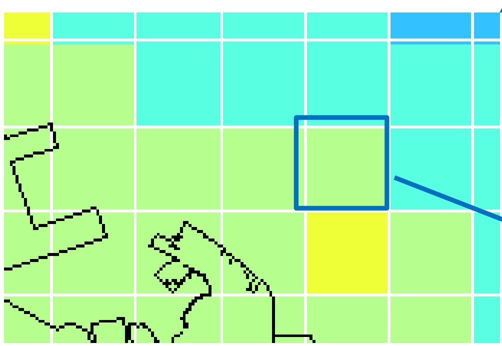
Theoretically, ΔT depends on grid scale and meteorology; in practice, ΔT fixed at 1 to 2 hours

Regional model calculations performed off-line i.e. nesting is a post-processing system

Regional meteorology drives local model

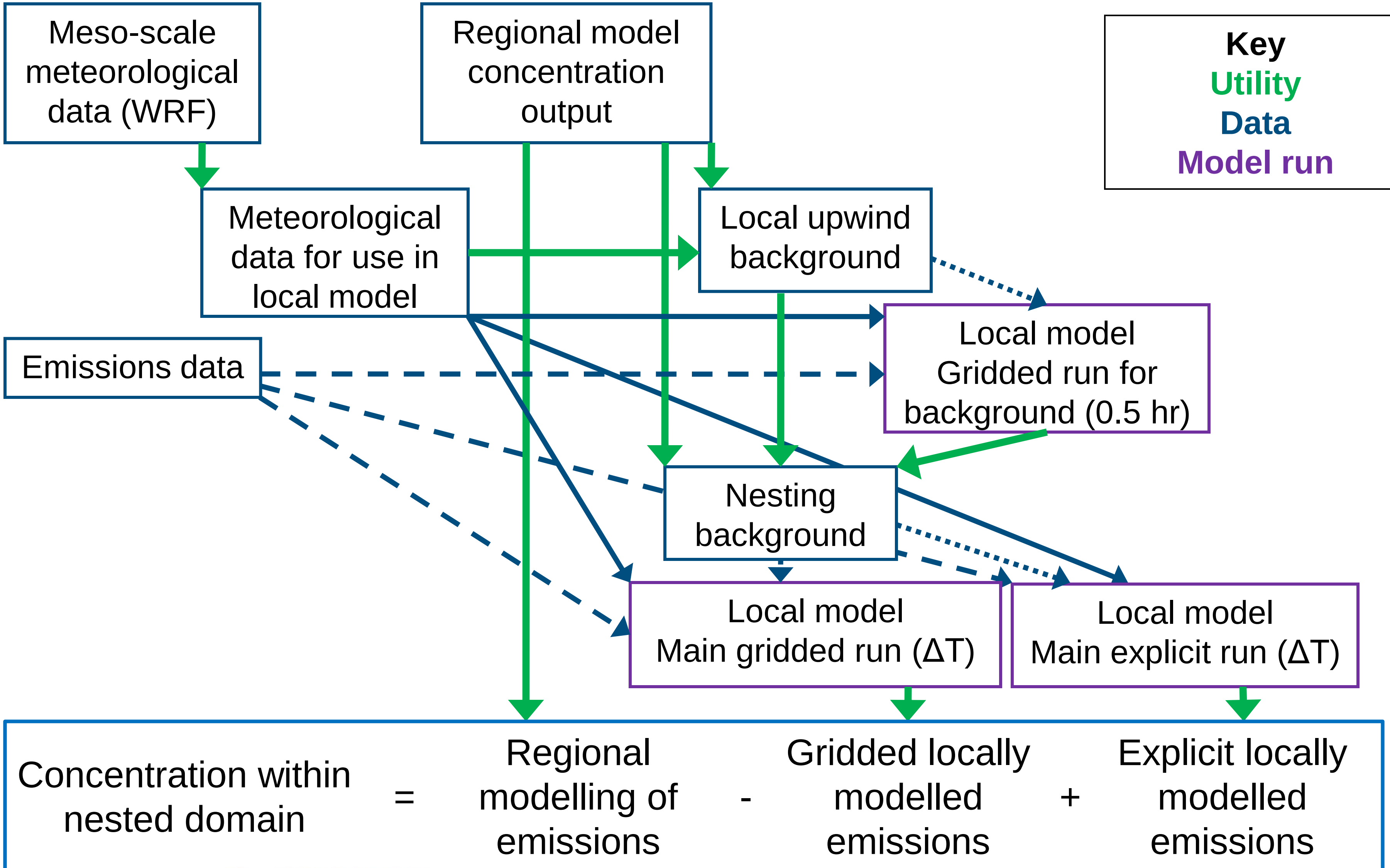
Concentration within nested domain = Regional modelling of emissions - Gridded locally modelled emissions (ΔT) + Explicit locally modelled emissions (ΔT)

Consistent emissions used in both models

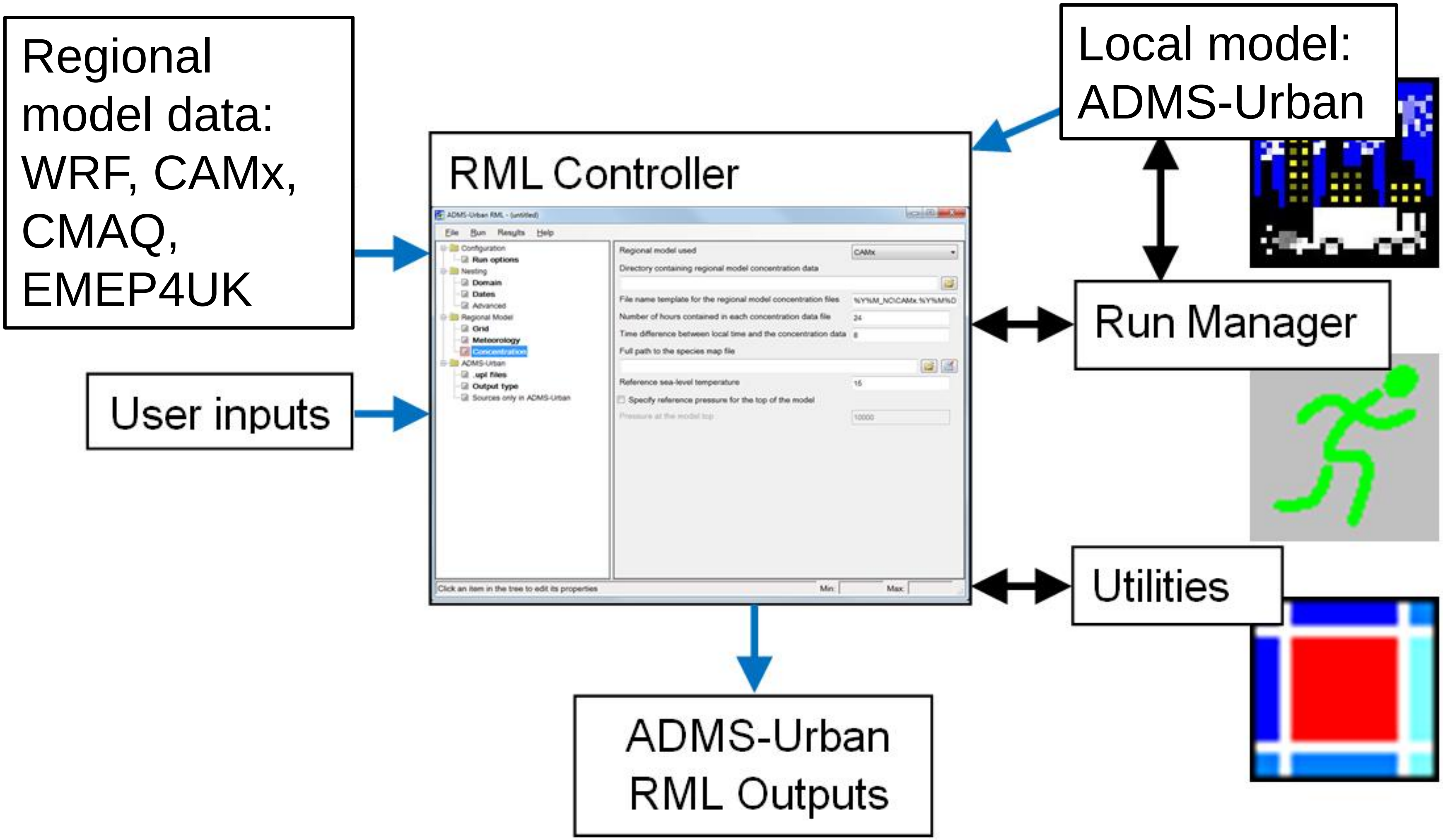


Nesting calculations performed separately for each regional model grid cell

System implementation



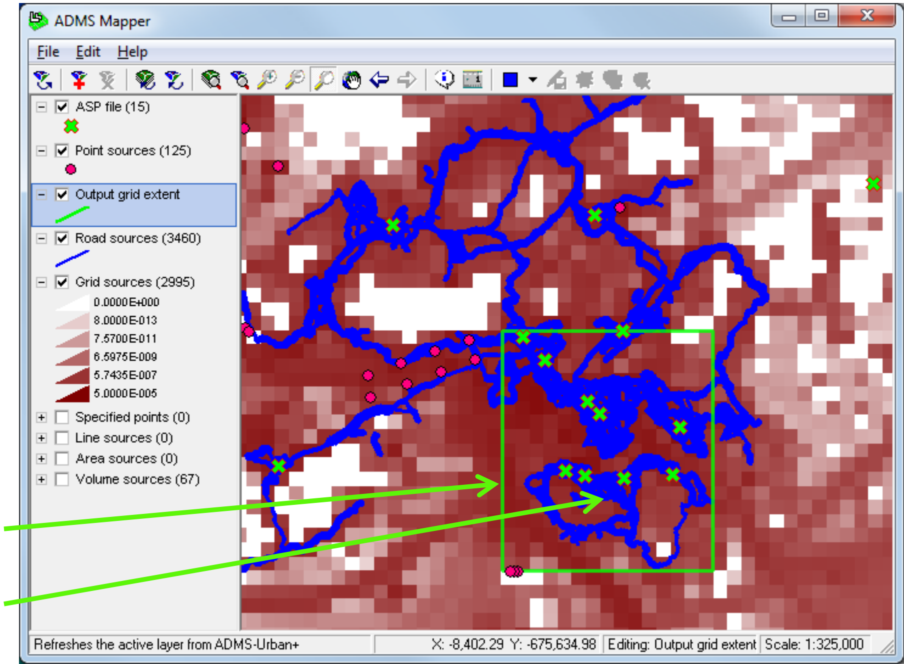
System implementation: components



Example use of system

- **Domain:** Hong Kong Special Administrative Region (HK SAR)
- **Period:** 2010
- **Regional models:** WRF (v 3.2) and CAMx (v 5.4)
- **Input data:**
  - 1 km regional model data (Yao *et al.*, 2014)
  - Gridded emissions data as used in CAMx
  - For major roads, traffic flow, speed and location data
  - Point source information

Emission sources & output locations



Contouring domain

Monitors

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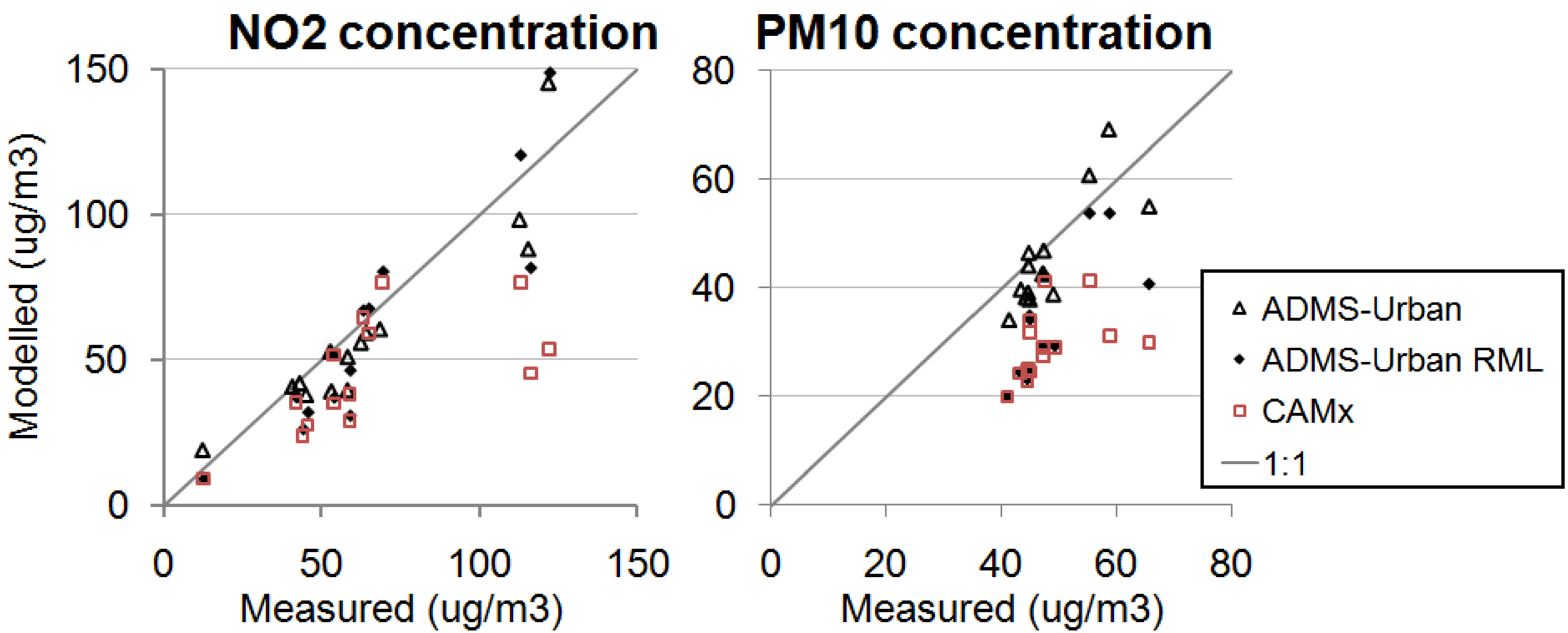
Example use of system

- **System configuration:**
  - Larger nesting domain to cover all monitor locations (72km x 49 km)
  - Smaller nesting domain for contour runs covering Hong Kong urban areas (15 km x 17 km)
  - ΔT = 1 hour
  - 7 desktop computers, one for RML Controller, 6 for ADMS-Urban runs
- **Run times for 1 year:**
  - Validation run at monitors – 6 hours
  - Contour output – 1 to 2 weeks (processor availability dependent)
- **Validation methodology:**
  - 13 continuous monitors:
    - 3 roadside
    - 10 urban background
    - 1 rural

Example use of system

- **Results: validation at monitors**
  - △ ADMS-Urban (uses measured background concentrations & meteorology)
  - ◆ ADMS-Urban RML
  - □ CAMx



Example use of system

- **Results: validation at monitors**

ADMS-Urban (uses measured background)

ADMS-Urban RML

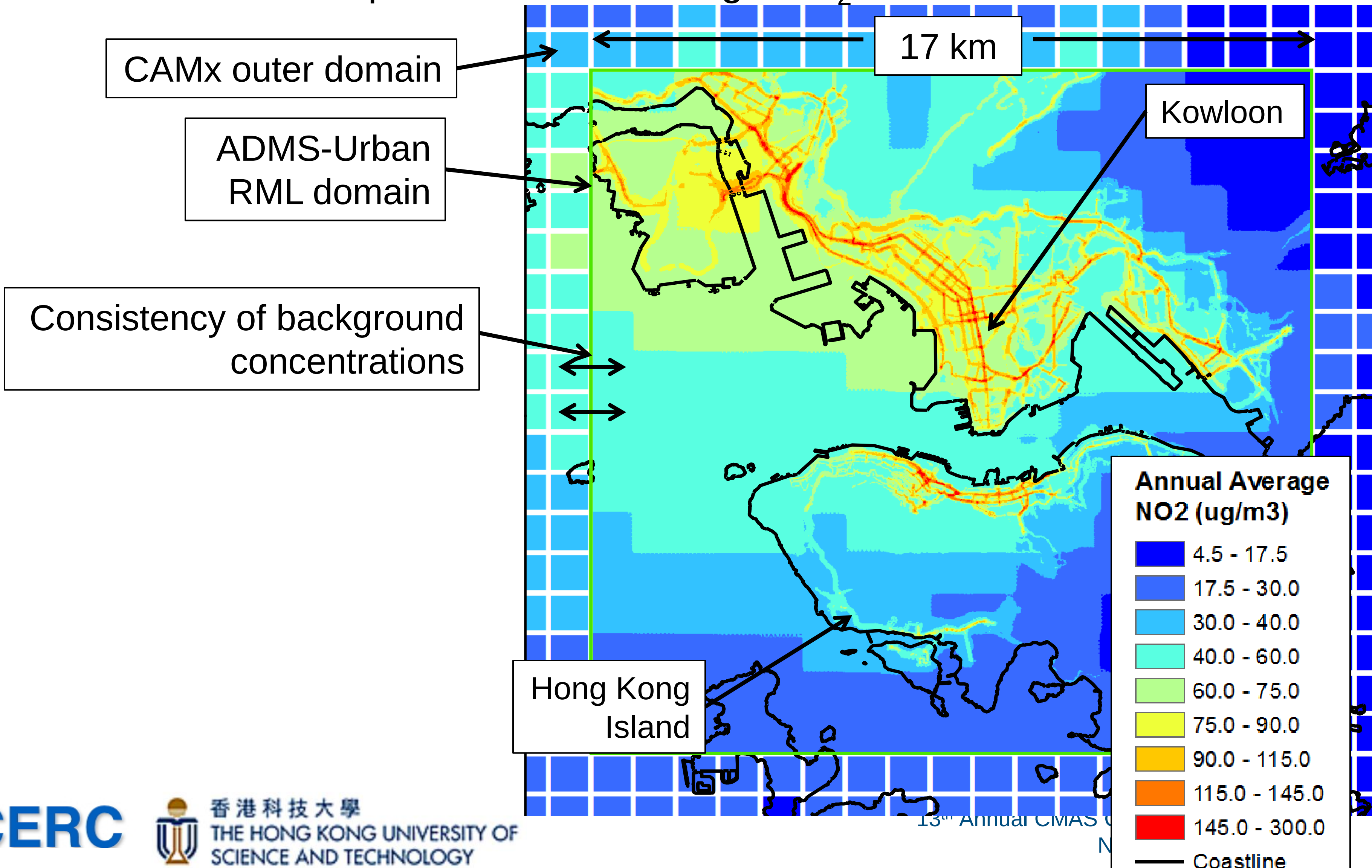
CAMx

NO_2 statistics

Site type	Sites	Model	Observed (µg/m³)	Modelled (µg/m³)	R	Fac2
Roadside	3	ADMS-Urban	116.6	110.6	0.60	0.88
		ADMS-Urban RML	117.2	117.1	0.57	0.88
		CAMx	117.2	58.5	0.49	0.45
Background	10	ADMS-Urban	54.7	48.0	0.58	0.81
		ADMS-Urban RML	55.6	47.7	0.56	0.73
		CAMx	55.6	44.1	0.54	0.68
Rural	1	ADMS-Urban	12.5	19.0	0.57	0.86
		RML (nested)	12.7	9.0	0.30	0.52
		CAMx	12.7	9.0	0.30	0.52

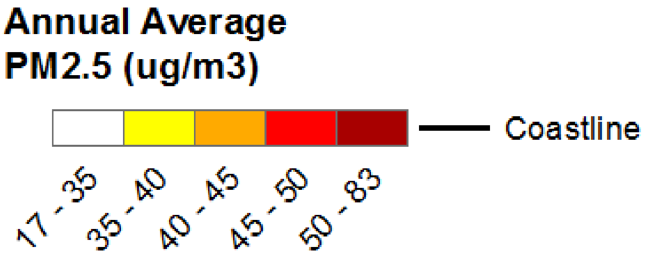
Example use of system

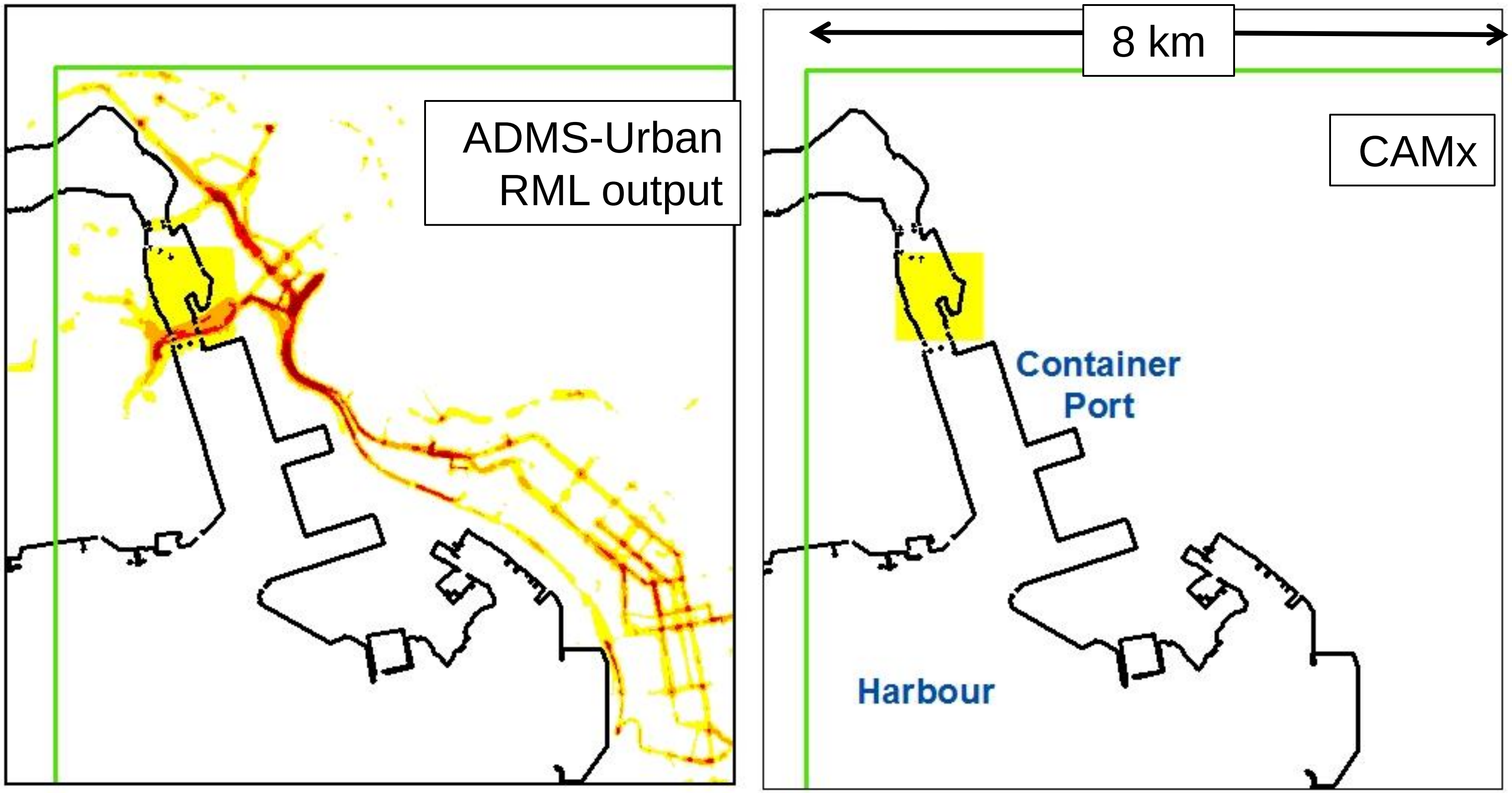
- **Results:** contour plot of annual average NO_2



Example use of system

- **Results:**
  - Contour plot for $PM_{2.5}$
  - Exceedences of the annual average air quality objective, 35 µg/m³





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Conclusions

- Fully automated system based on Stocker et al. (2012) that nests the local dispersion model ADMS-Urban in a regional model (RM)
- Full range of gaseous and particulate pollutant species modelled
- Meteorology and background from each RM grid cell used in local modelling
- In rural locations, ADMS-Urban RML results the same as RM results, as there are no local sources
- In urban locations, ADMS-Urban RML results differ from RM results, particularly for NO_x species where the effects of local sources and street canyon morphology dominate the concentrations
- The example demonstrates that the ADMS-Urban RML performs better than CAMx at roadside sites

Acknowledgements

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Environmental Protection Department
The Government of the Hong Kong Special Administrative Region