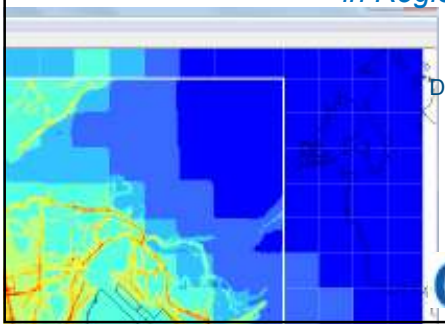
Air Quality Forecasting Nesting Local Street Level Model in Regional Model



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13 June 2017

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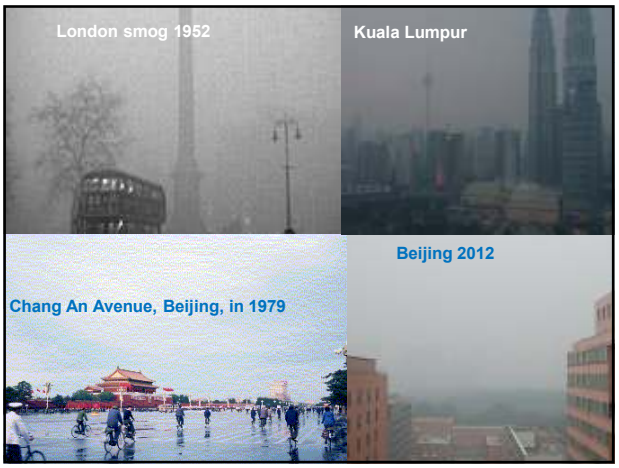
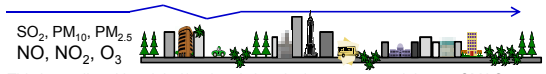


Contents 内容

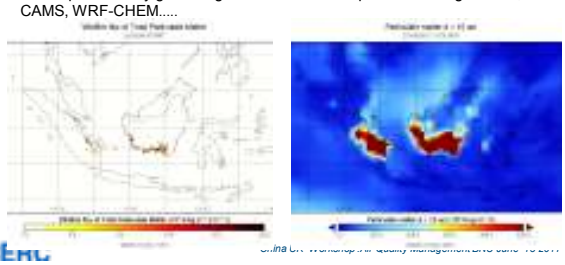
- Regional effects and modelling
- Local effects and modelling
- Nesting local model in regional model
- Example use of system
- Conclusions

Regional effects

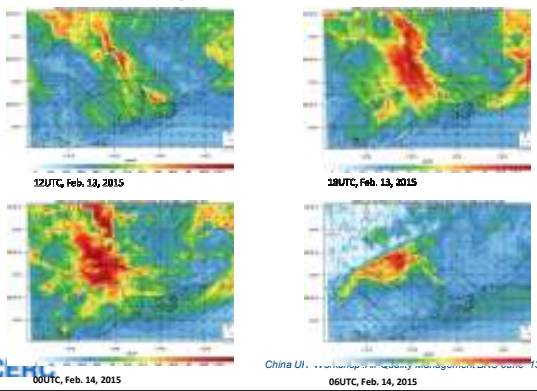
- Regional pollution need to feed into an urban air quality forecasting system



- This is predicted by global/regional chemical transport models e.g. CMAQ, CAMS, WRF-CHEM.....



Regional Effects
Chemical Transport Model - CMAQ



Regional Models

- Issues with running regional models at high resolution include:
- 高分辨率运行区域模型存在问题
  - Difficult to include explicit modelling of roads and near-source features, e.g. street canyons难以详细模拟道路和污染源附近特征—例如街道窄谷
  - Run times and data storage requirements become prohibitive
  - 运行时间和数据存储的可行性

Local effects – Many influences

- Many influences which vary on small spatial scale:
  - Variable emissions
  - Variable building height and density causing complex urban canopy flow
  - Street canyons

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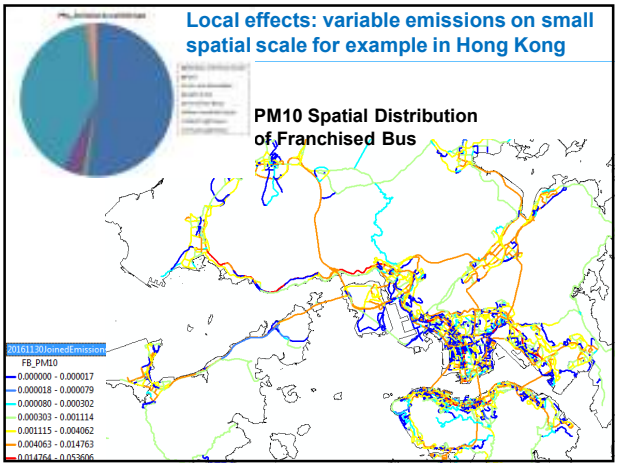
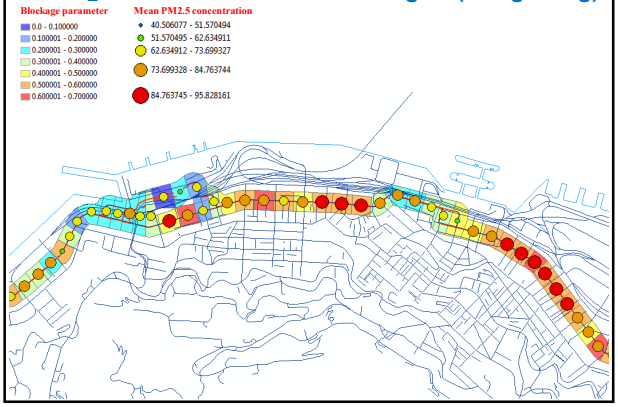
Local effects: variable emissions on small spatial scale for example in Hong Kong

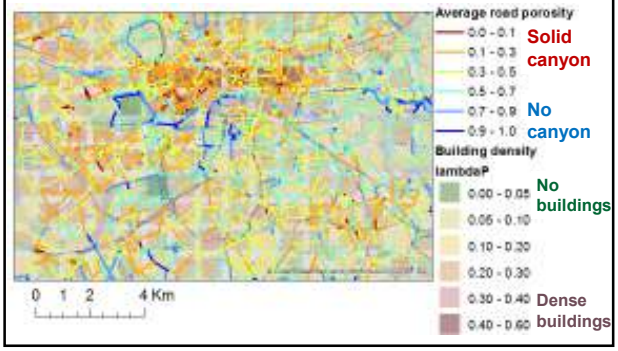


Local Effects – density of buildings: Average measured PM2.5 in each grid (Hong Kong)



Advanced street canyons: Porosity

Central London road porosity and 1 km building density values



Urban pollution modelling
Neighbourhood and local scale dispersion with ADMS-Urban

- ADMS-Urban is designed to model dispersion from a **wide range of urban sources**
- **Gaussian type model** with point, line area, road and grid sources
- Concentration calculated at **high resolution** (<10m)
- Fully integrated **urban canopy flow** and **street canyon** modules
- Includes **meteorological pre-processor**
- Models **chemical** & **deposition** mechanisms; allows for effects of **complex terrain**
- **Link**s to regional models through **regional model link (RML)**
- Integration with **Geographical Information Systems** (GIS) and an **Emissions Inventory Database** (EMIT)
- Used in many major cities for **air quality management, forecasting** etc: e.g. London, Manchester, Budapest, Rome, Barcelona, Hong Kong, Beijing, Shanghai, Delhi, Kuala Lumpur, Singapore, Cape Town

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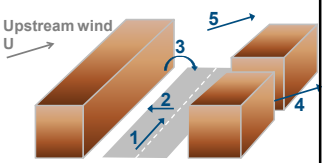
Advanced Canyon改进的窄谷
Theory: Canyon effects 窄谷效应

5 principal effects of street canyons on dispersion

1. Pollutants are channelled **along** street canyons
2. Pollutants are dispersed **across** street canyons by circulating flow at road height
3. Pollutants are trapped in **recirculation** regions
4. Pollutants leave the canyon through gaps between buildings as if there was **no canyon**
5. Pollutants leave the canyon from the **canyon top**

窄谷效应对扩散的5个主要影响

1. 污染物**沿街道窄谷**输送
2. 污染物在道路高度处受环流气流影响**穿过**窄谷
3. 污染物被困在**回流区**
4. 污染物从建筑物间的空隙离开，与**无窄谷**情况相似
5. 污染物从**窄谷顶部**离开



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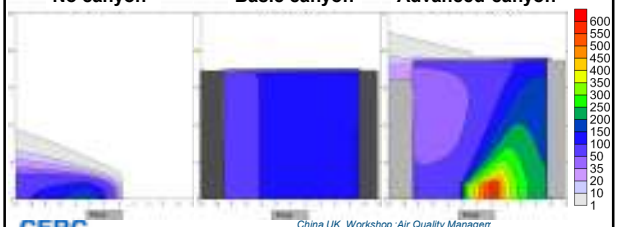
Canyon cross-section contours
窄谷横截面浓度分布图

- Canyon with properties set to those for London KC5 monitoring site – Earls Court Road
- Slight asymmetries in height, width and porosity
- 高度略为不对称，宽度，建筑的间隙度
- Concentrations for one example hour

Upstream wind

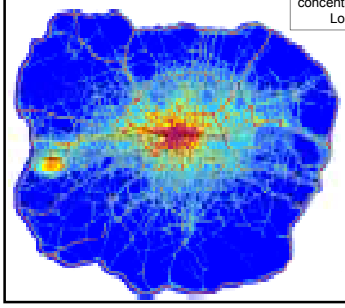
No canyon **Basic canyon** **Advanced canyon**

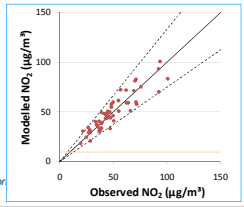


Example and validation using ADMS-Urban

- Given accurate inputs (e.g. adjusted to account for real-world emissions) comparison with measurements at roadside and background sites good for long term averages.

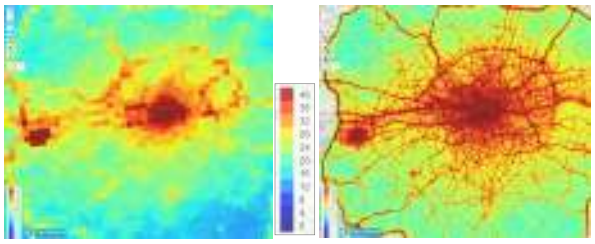
Long-term average NO_2 concentrations in Greater London (2012)





Context: Regional model vs Local model (ADMS-Urban):London

- 1km resolution model vs ADMS-Urban street level resolution



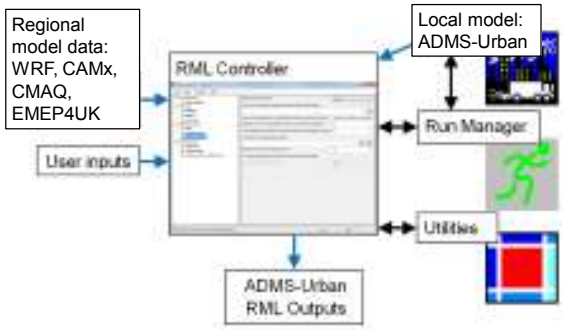
Annual average NO_2 concentrations

Advantages of nested system: local model within regional model

- What are the advantages of a nested system of models?
- 嵌套系统的优势

Model feature 模型特点	Model	
	Regional (eg grid based) 区域（例如基于网格）	Local (eg Gaussian plume) 本地（例如高斯烟羽模型）
Domain extent 尺度	Country (few 1000 km) 区域（1000km）	City (50km) 城市（50km）
Meteorology 气象	Spatially and temporally varying from meso scale models 中尺度模型随空间和时间变化数据	Usually spatially homogeneous 通常为空间一直数据
Dispersion in low wind speed conditions 在低风速条件下扩散	Models stagnated flows correctly 正确模拟停滞气流	Limited modelling of stagnated flows 模拟停滞气流受到限制
Deposition and chemical processes 沉降与化学过程	Reactions over large spatial and temporal scales 大的空间与时间尺度反应	Simplified reactions over short-time scales 较短时间尺度的简单反应
Source resolution 污染源分辨率	Low 低	High 高
Validity 验证	Background receptors 背景接受点	Background, roadside and kerbside receptors 背景、路边和街边接受点

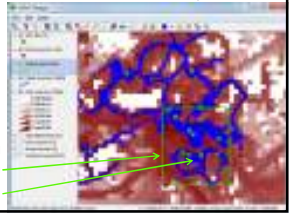
System implementation: components



Example use of system 案例应用-香港特别行政区

- **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
  - 主要道路、交通流、速度和位置
  - Point source information
  - 点源信息

Emission sources & output locations

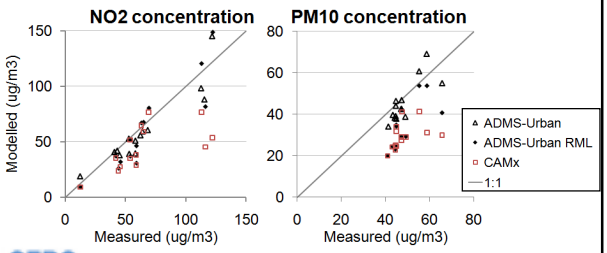


Contouring domain

Monitors

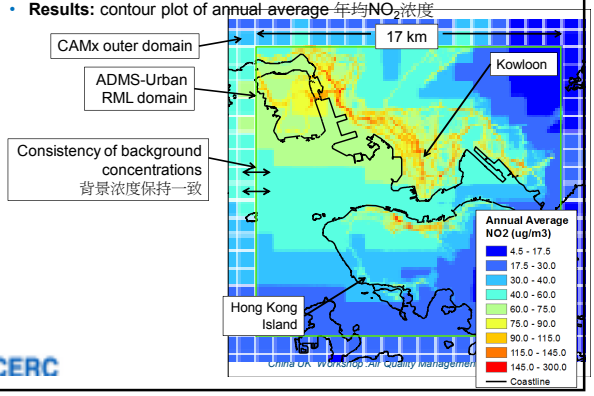
Example use of system 案例应用-香港特别行政区

- **Results: validation at monitors 监测点结果验证**
  - ADMS-Urban (uses measured background concentrations & meteorology)
  - ADMS-Urban RML 嵌套系统
  - CAMx

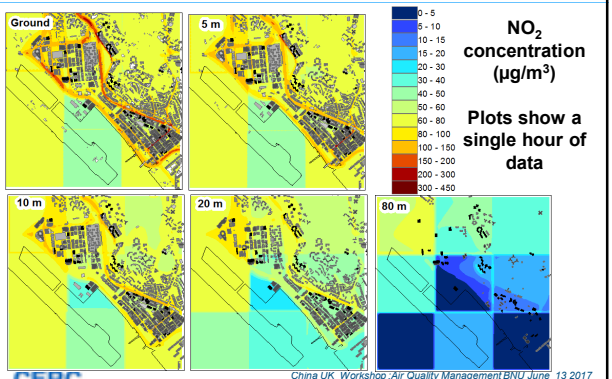


Example use of system

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

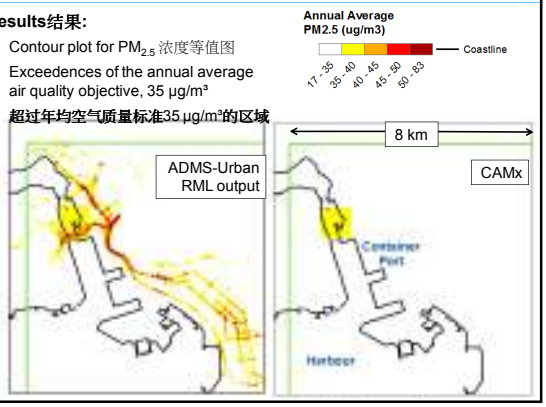


Example use of the system: Contour output at different heights



Example use of system 案例应用-香港特别行政区

- **Results结果:**
  - Contour plot for $PM_{2.5}$ 浓度等值图
  - Exceedences of the annual average air quality objective, 35 µg/m³
  - **超过年均空气质量标准35 µg/m³的区域**



Conclusions 结论

- 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 are 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
- 将ADMS-城市嵌套与区域模型的全面自动化的系统
- 全面的气态和颗粒污染物模拟
- 本地模拟采用区域模型每一网格的气象数据和背景浓度
- 在无本地污染源的农村站点，嵌套系统的结果与区域模型相同
- 在城区站点，嵌套模型结果与区域模型不同，特别是收到本地污染源和街道窄谷影响的NOx

Acknowledgements 致谢

The ADMS-Urban RML system has been developed in collaboration with researchers from the Hong Kong University of Science and Technology, supported by the Hong Kong Environmental Protection Department.