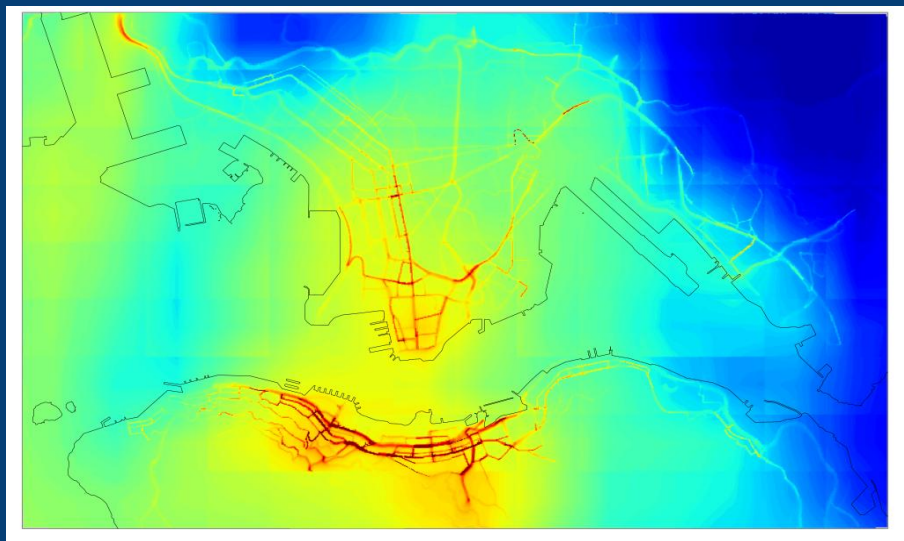


Using air dispersion models to assess baseline air quality and develop mitigation policies



Amy Stidworthy, Jenny Stocker,
David Carruthers, Christina Hood,
Mark Jackson

amy.stidworthy@cerc.co.uk

Cambridge Environmental Research Consultants

CERC

- SME
- Based in Cambridge, UK
- Experts in air quality since 1985

CERC activities

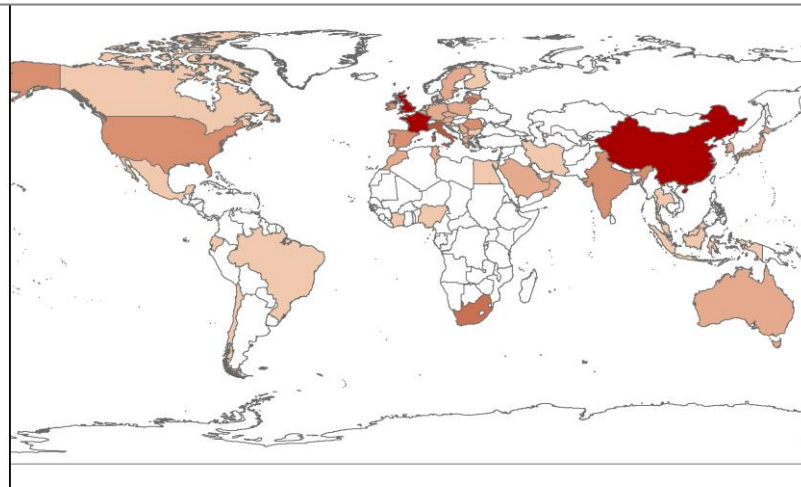
- ADMS model development
- Partner in air quality research projects
- Air quality consultancy (EIA, AQM, Permitting)
- ADMS model licensing, support and training

CERC clients

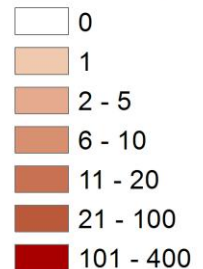
- Commercial air quality consultancies
- Local/national government agencies
- Industry operators
- Academic institutions



Hundreds of ADMS licences worldwide



Organisations using
CERC software
per country



Contents

What modelling adds to measurement data

Air quality modelling using CERC's ADMS model

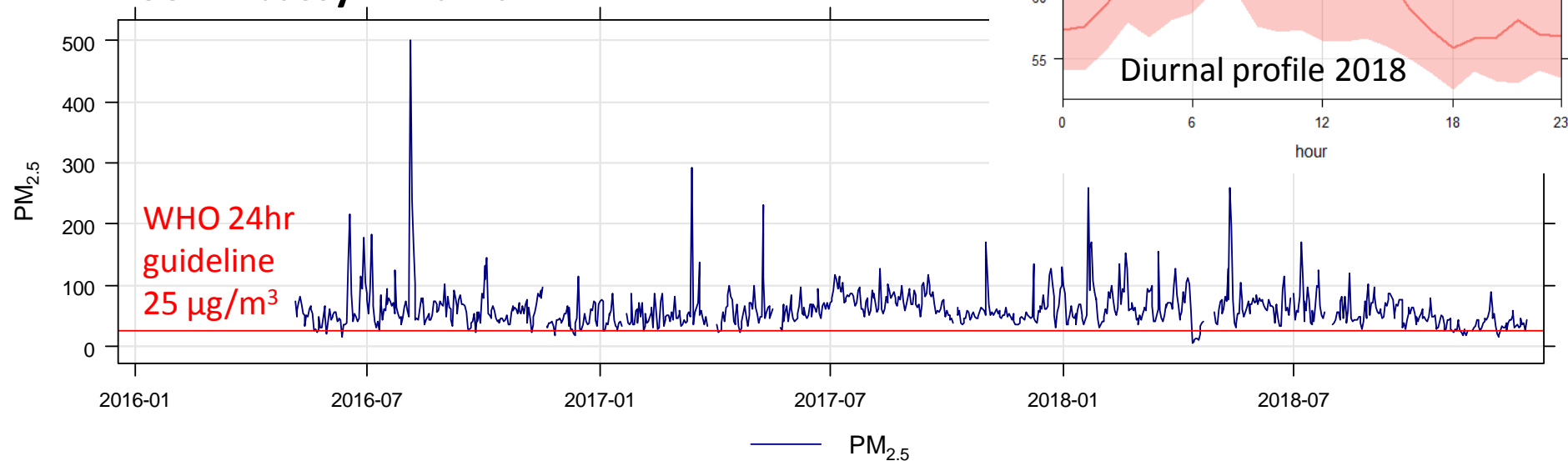
Input requirements for air quality modelling using ADMS

Example air quality modelling projects using ADMS

Starting point: measurements

- What measurements tell us:
 - Air quality values *at specific locations* to compare to standards
 - High frequency data
 - Large networks of monitors can give some information about spatial variations

Daily average PM_{2.5} ($\mu\text{g}/\text{m}^3$) at the
US Embassy in Bahrain

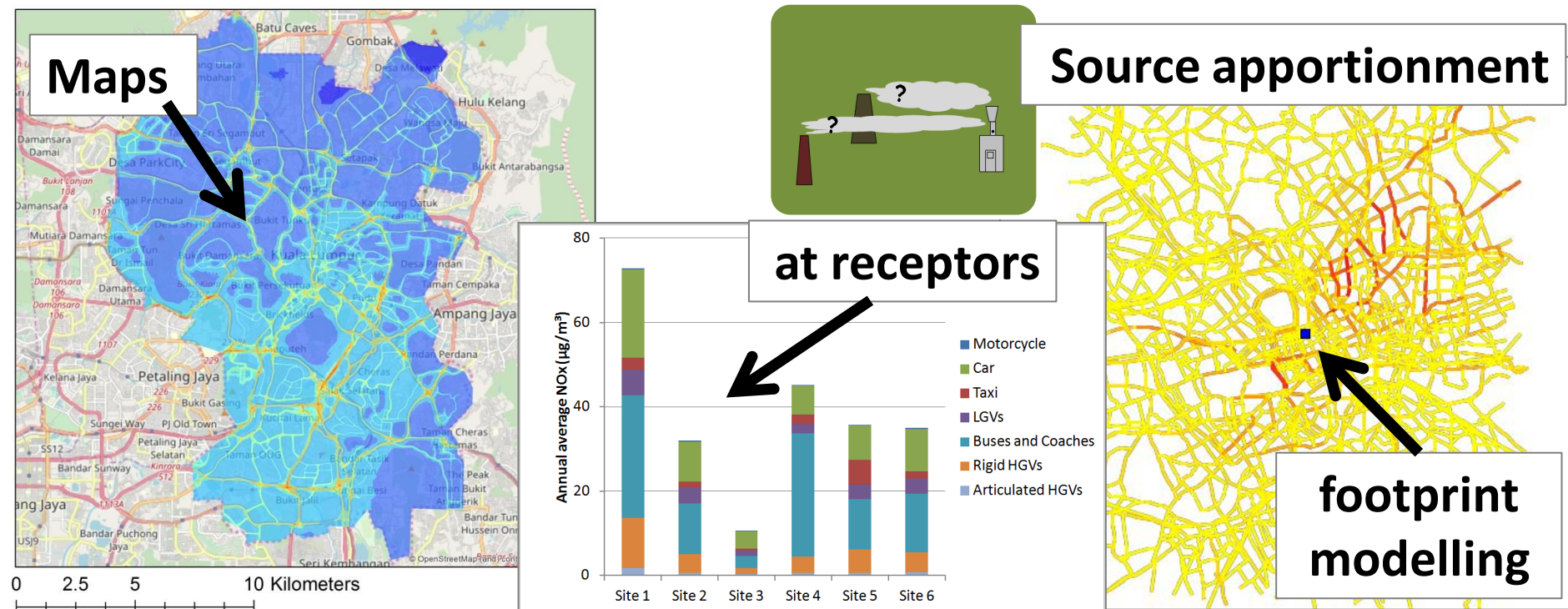


Starting point: measurements

- What measurements tell us:
 - Air quality values *at specific locations* to compare to standards
 - High frequency data
 - Large networks of monitors give some information about spatial variations
- Restrictions:
 - Lack of spatial extent
 - Historic records only
 - Uncertainty:
 - **Reference monitors** are generally accurate, although PM measurements have a *relatively* high uncertainty, which increases with PM magnitude (e.g. 27 % at 100 $\mu\text{g}/\text{m}^3$)
 - **Low-cost sensors** have a *relatively* high uncertainty

What modelling adds to measurement data

- What modelling can tell us:
 - Street-scale resolution, hourly air quality values at all locations (maps, time series)
 - Air quality forecasts (requires forecast meteorological data)
 - Source apportionment (including footprint modelling)
 - Scenario testing for pollution mitigation



What modelling adds to measurement data

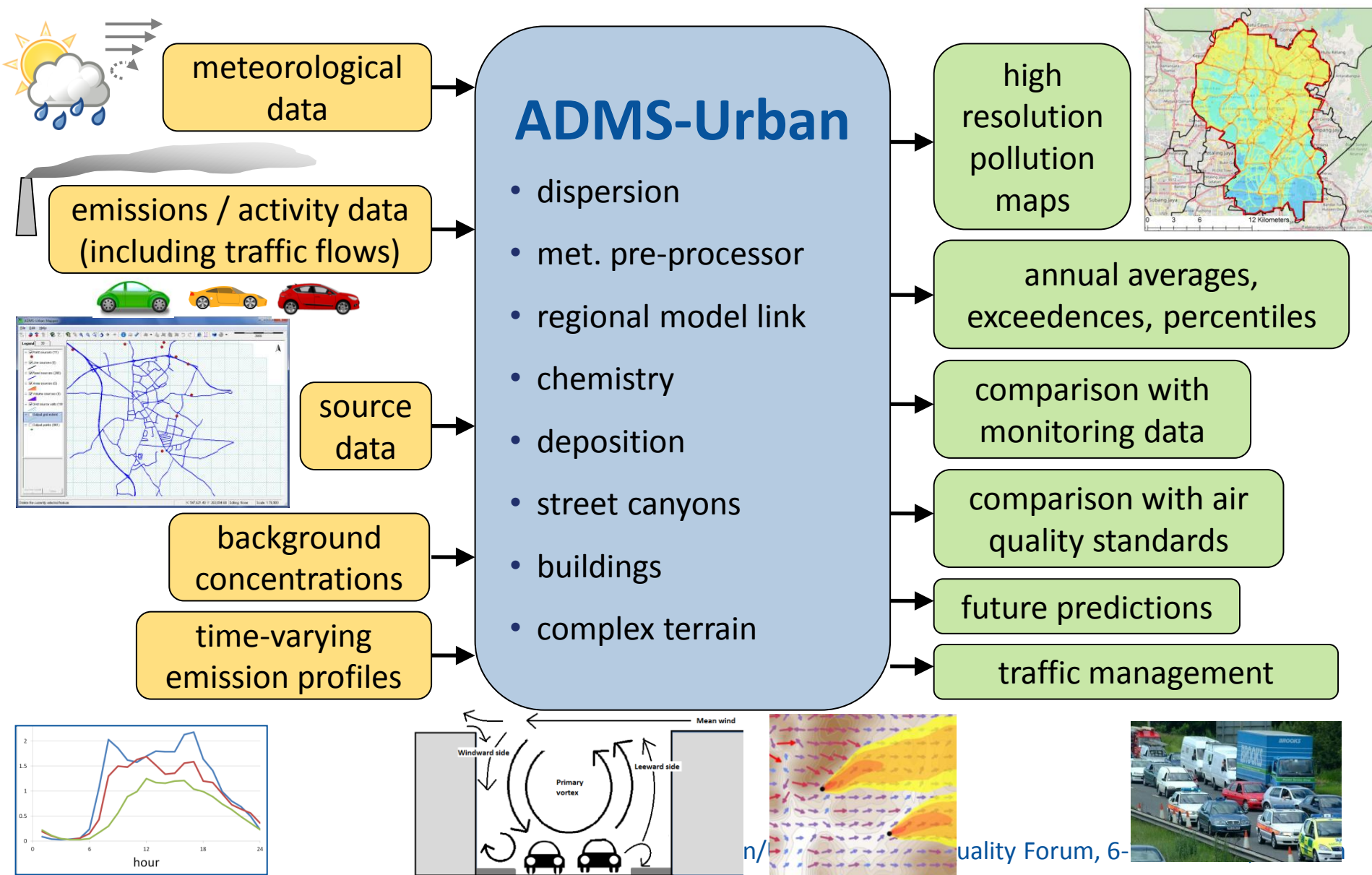
- How do we know the model gives the correct values?
 - Compare the model predictions to reference measurements
- ‘Modelling’ is a 3-stage process:
 - **STEP 1:** Set up / refine model for domain of interest (e.g. Manama urban area, or all of Bahrain)
 - **STEP 2:** Output predictions of pollutant concentrations at measurement locations & compare to measurements
 - **STEP 3:** Apply model:
 - Maps of current air quality
 - Forecasting (measurement data assimilation optional)
 - ‘What if?’ scenario testing for pollution mitigation
 - ...



**Repeat STEP 1 &
STEP 2 until
good agreement**

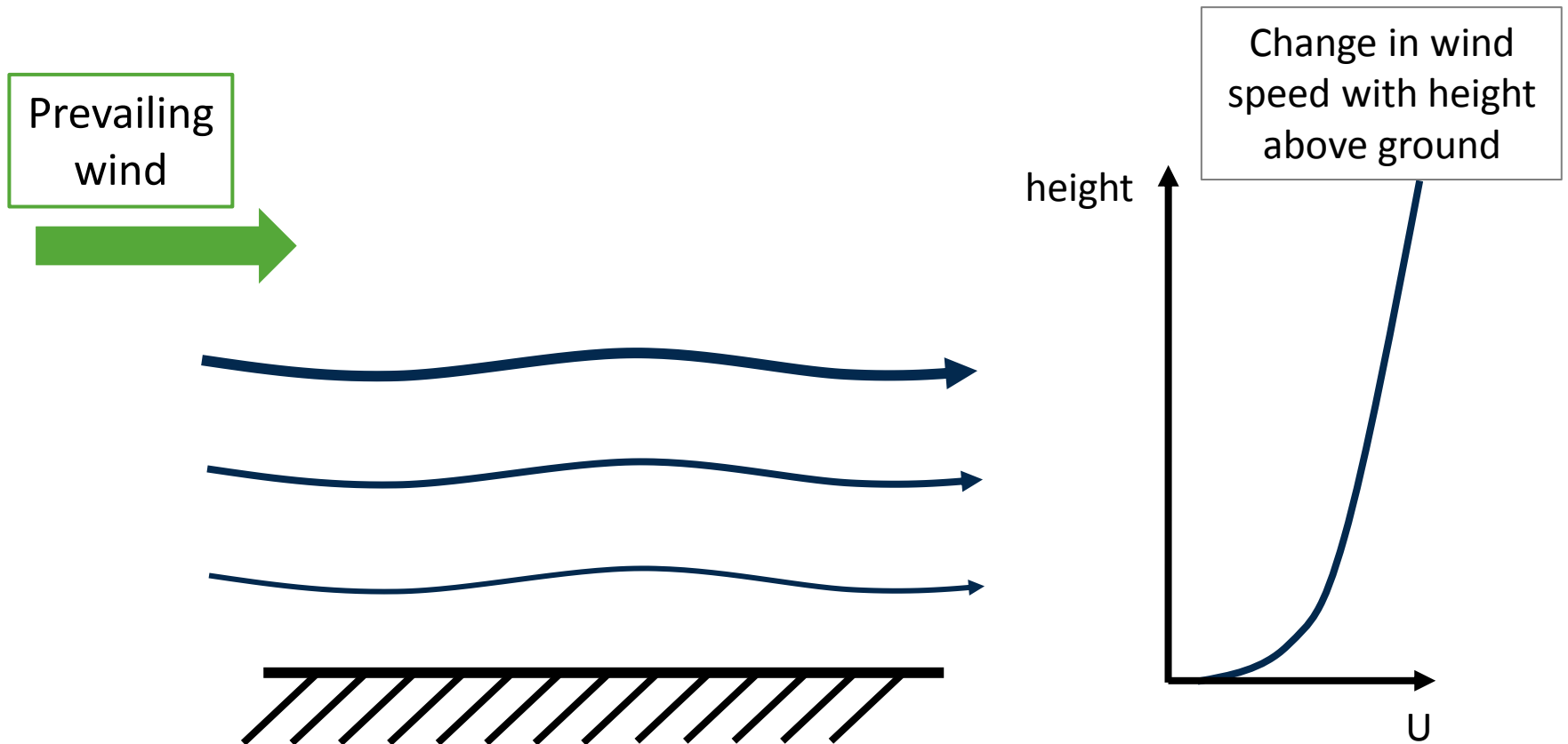
Air quality modelling using CERC's ADMS model

Air quality modelling using ADMS-Urban



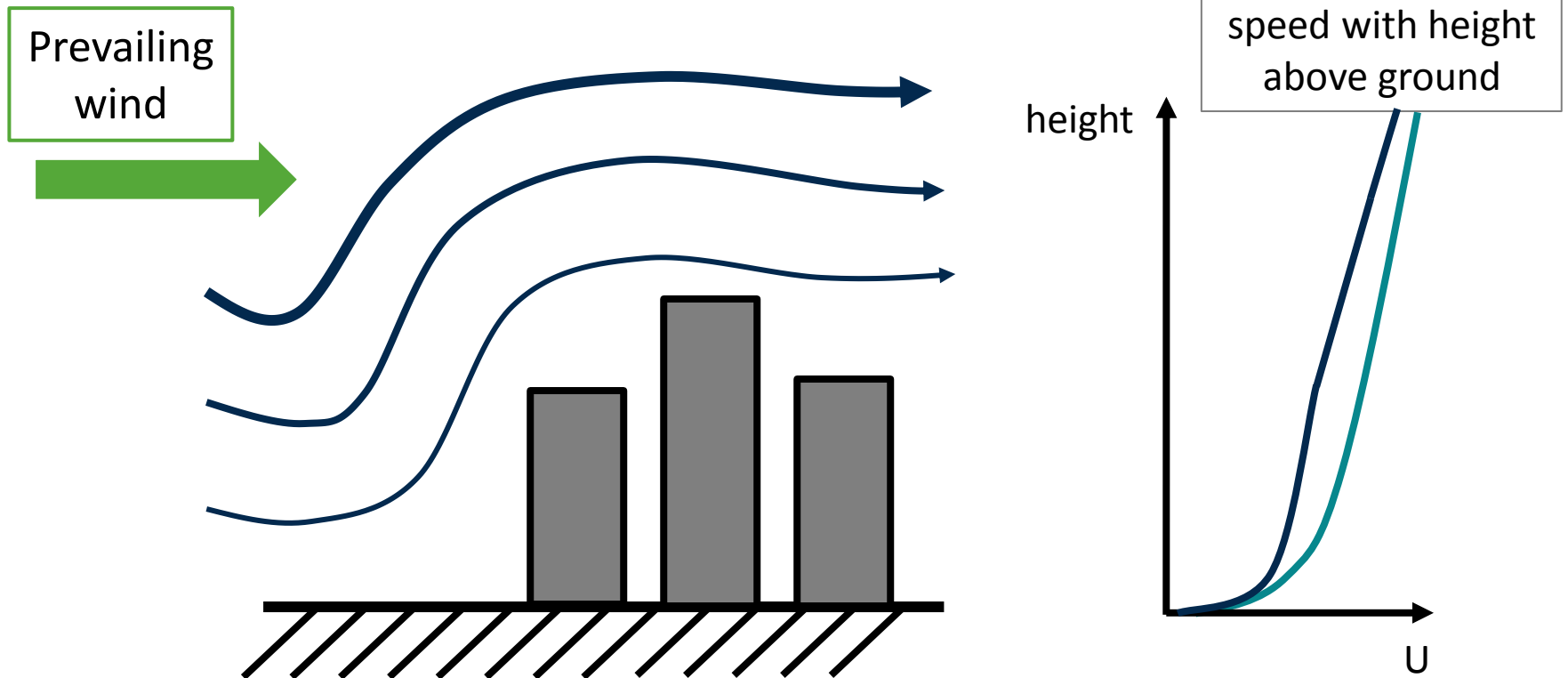
Urban flow field modelling

- If there are no obstructions to air flow or complex terrain
- Wind speed profile remains approximately spatially homogeneous with vertical gradient



Urban flow field modelling

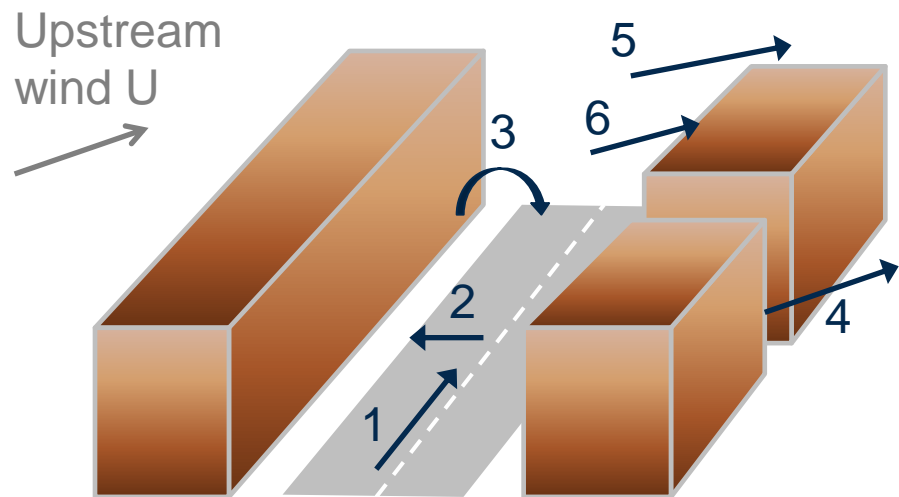
- Buildings impact on air flow in urban areas
- Wind speed profile spatially inhomogeneous
- Within building canopy: wind speed reduced, turbulent intensity increased



Street canyon modelling

Tall buildings form 'street canyons' where pollutants:

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



Overview of air quality modelling using ADMS-Urban

- **ADMS – Atmospheric Dispersion Modelling System**
- Widely used in the UK, Europe and worldwide (Hong Kong, Singapore, Beijing, Delhi, London...) by companies, regulatory bodies, local and national government, and research organisations for...

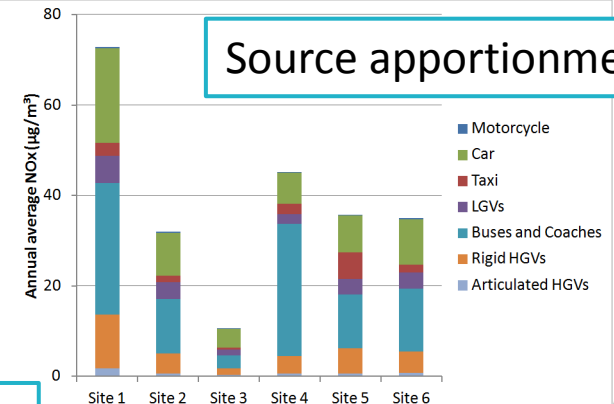
Air Quality Management Areas

Planning applications

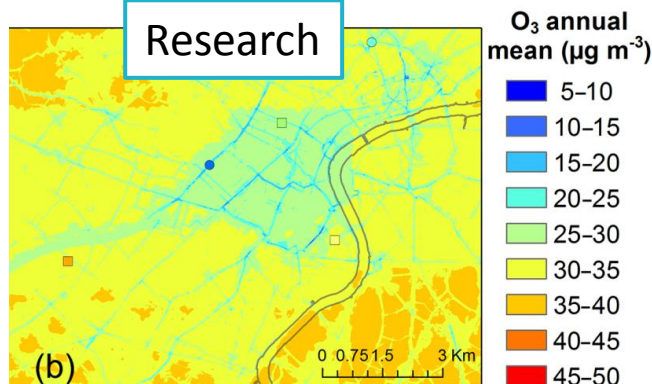
Permitting applications

Policy assessment

Source apportionment



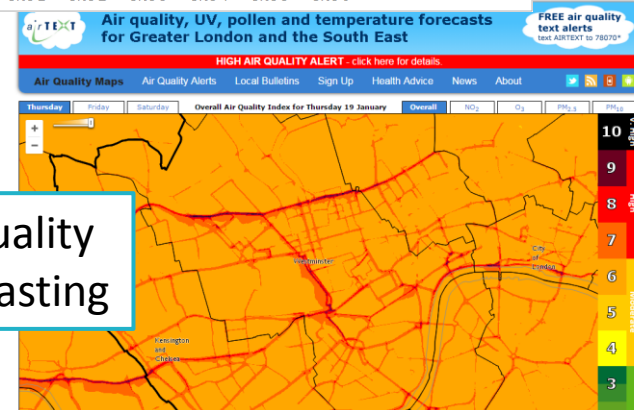
Research



Stack height determination

Inputs to health studies

Air quality forecasting



Input requirements for air quality modelling using ADMS

Requirements for detailed air quality modelling:

Meteorological data

- Hourly wind speed, direction, temperature and cloud cover are minimum requirements
- Measured or modelled data
- Meteorological influence on dispersion of emissions from traffic more complex as affected by local urban form



Rate of mixing relates to:

- plume properties
- meteorological conditions

Wind speed and direction



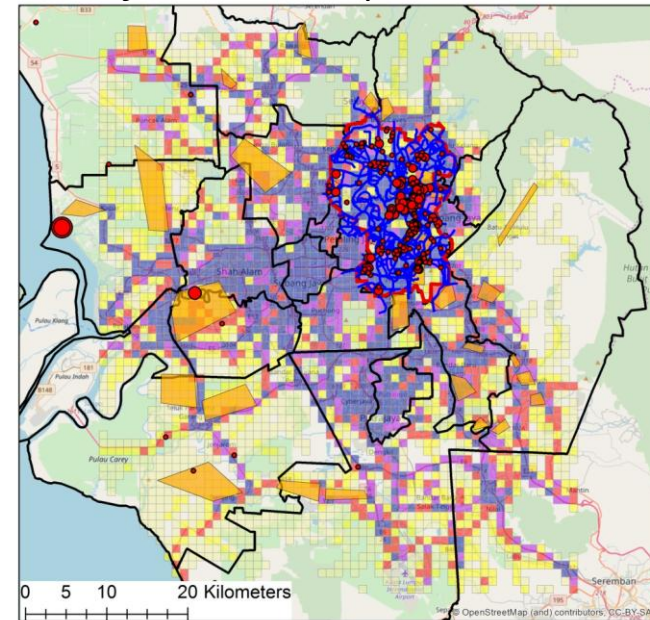
The Met Pre-Processor in ADMS calculates the structure of the atmospheric boundary layer from the input meteorological data and site characteristics, e.g. surface roughness

Requirements for detailed air quality modelling:

Emissions data

- ADMS-Urban requires **emission rates** and **source characteristics**:
 - Emissions rates e.g. g/s, g/km/s:
 - Source characteristics:
 - Geometry
 - Efflux parameters (important for industrial sources)
- Compile emissions from significant sources
- The methods used depend on the data available, e.g...

Emissions inventory compiled by CERC for Kuala Lumpur



“Bottom-up” approach

- Detailed source-by-source emissions accounting:
 - Emissions monitoring/reporting (large industrial sources)
 - **Emission rate = Activity x Emission Factor**
- For example: road sources



“Top-down” approach

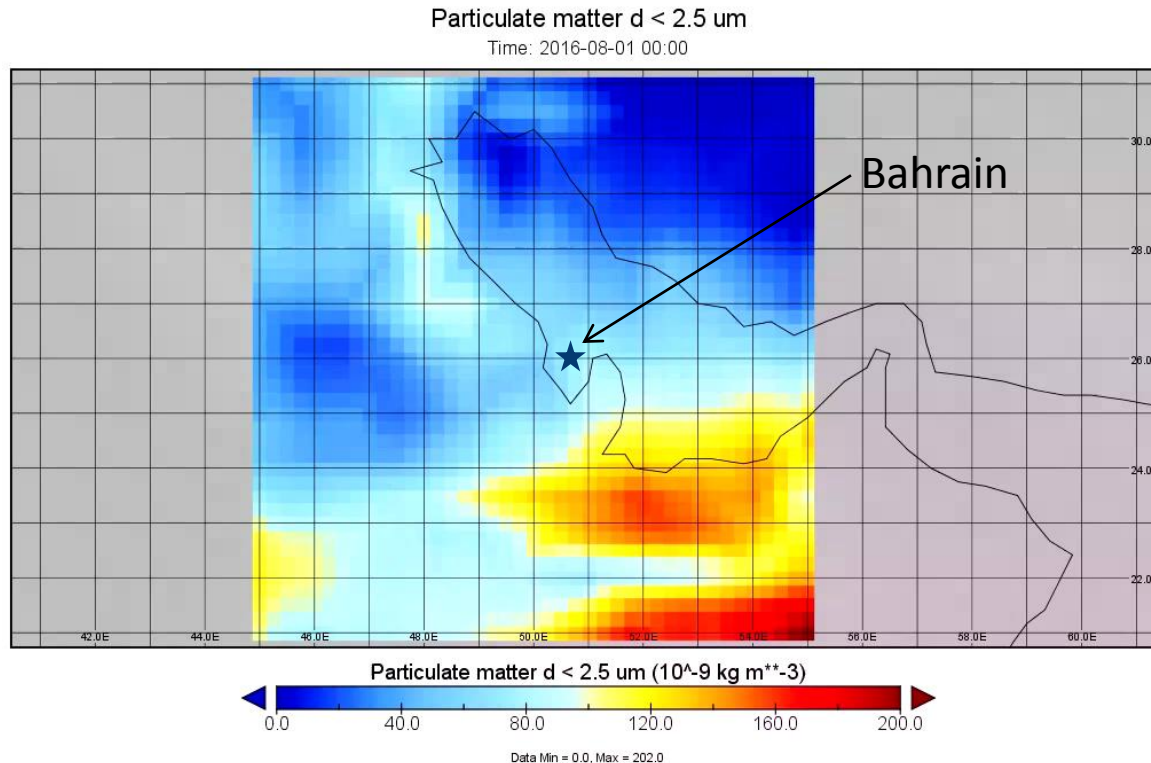
- Large-scale emissions accounting
- Scaling **national**/regional emissions by a **local** factor
- For example: gas emissions

Inversion techniques

- New approach combining data from networks of sensors with modelling to minimise emissions errors
- Takes emissions uncertainty and sensor data uncertainty into account

Requirements for detailed air quality modelling: Long-range pollutant transport data

CAMS Reanalysis PM2.5 ($\mu\text{g}/\text{m}^3$) for 1-14 Aug 2016



The CAMS Reanalysis dataset is freely available from the EU and combines global atmosphere composition modelling with satellite observations and in situ measurements:
atmosphere.copernicus.eu

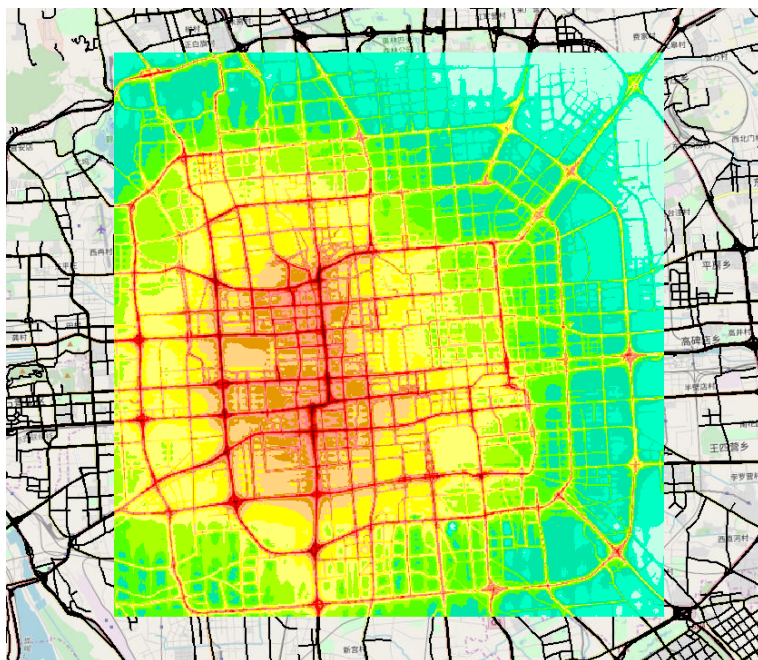
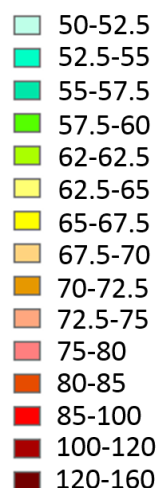
- Long-range transport of pollution from outside the local area is very important, particularly for dust events
- This can be accounted for in two ways in ADMS:
 - Regional monitoring data can be incorporated if available
 - The **ADMS-Urban Regional Model Link (RML)** has been developed to couple local modelling with regional-scale modelling (e.g. WRF-Chem, CMAQ, EMEP)

Example air quality modelling projects using ADMS

Air Quality modelling for health studies: Beijing

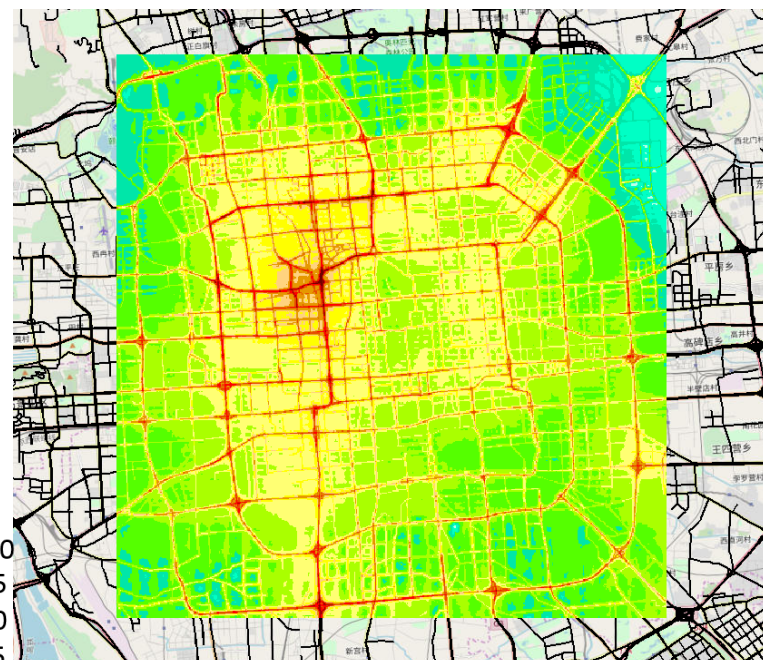
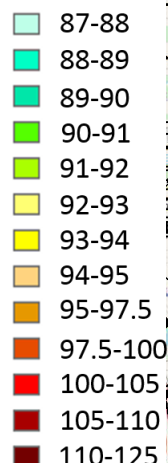
NO₂

$\mu\text{g}/\text{m}^3$



PM_{2.5}

$\mu\text{g}/\text{m}^3$



THE UNIVERSITY
of EDINBURGH



NATURAL ENVIRONMENT RESEARCH COUNCIL

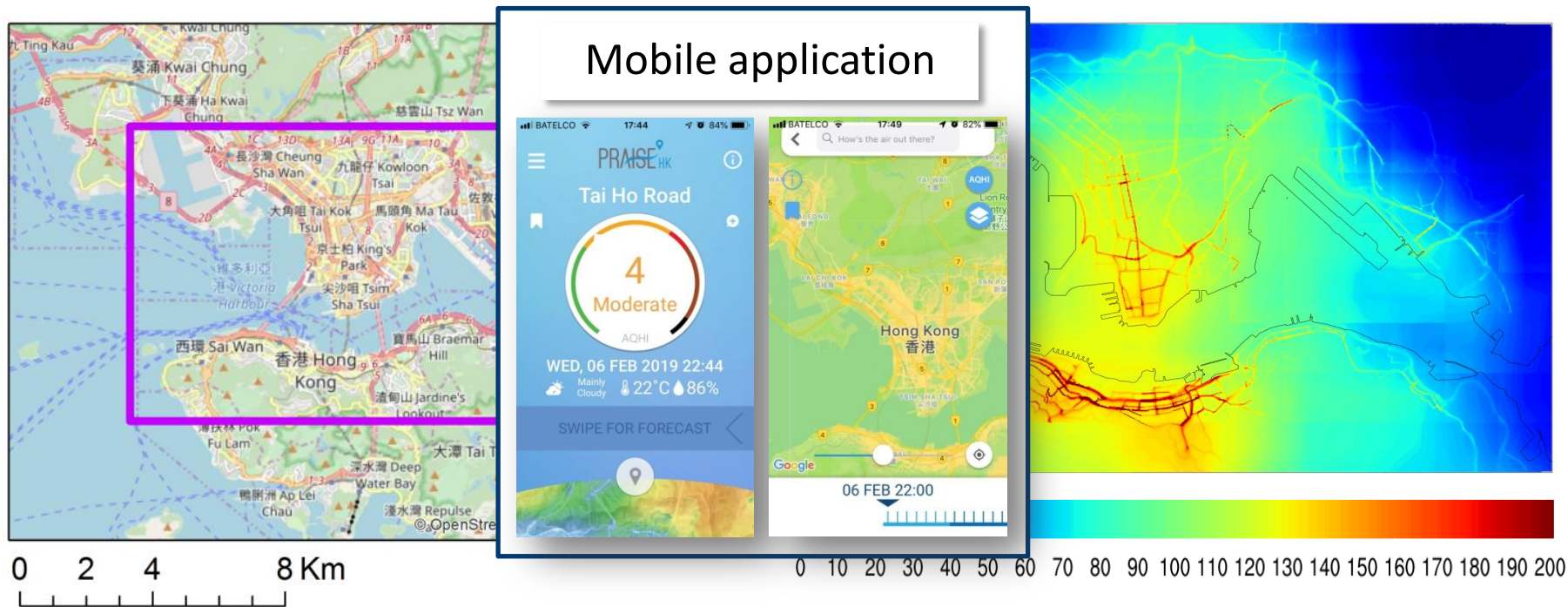
CERC

Air Quality and Haze in Beijing's Urban Environment - PhD thesis research work by M. Biggart, working at the University of Edinburgh (R. Doherty), also with Lancaster University (O. Wild, M. Hollaway) and CERC (J. Stocker, D. Carruthers)

Bahrain/UK Bilateral Air Quality Forum, 6-7 Feb 2019, Bahrain

Air quality forecasting: Hong Kong

Forecast NO_2 for Hong Kong and Kowloon, using ADMS-Urban coupled with regional model (CMAQ)



Working with **Prof Jimmy Fung**
and his team at the **Hong Kong**
University of Science and
Technology (HKUST)

CERC

PRAISE  **HK**

Empower the Public
with Personalised praise.ust.hk
Air Quality Information

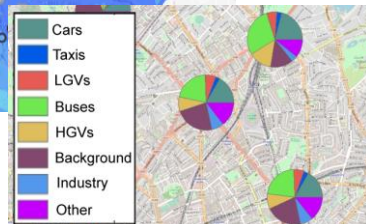
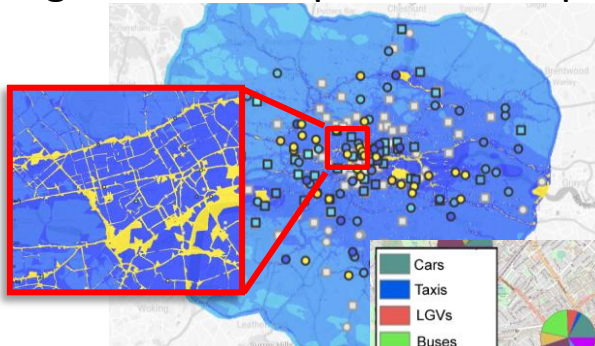
Bahrain/UK Bilateral Air Quality Forum, 6-7 Feb 2019, Bahrain

- A new 12-month project combining **modelling** with **measurements** from small low cost sensors and mobile monitors to provide new insight into London's air pollution problems



MODELLING

High resolution pollution maps

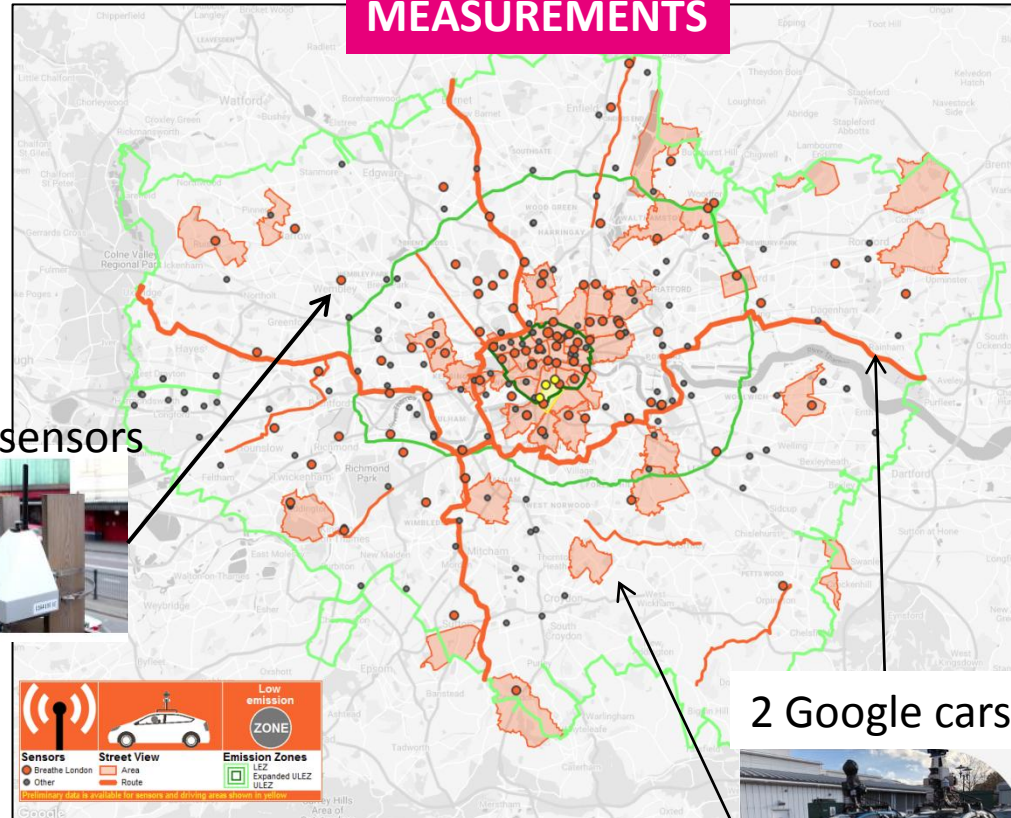


Source apportionment

100 low cost sensors



MEASUREMENTS



2 Google cars



Emissions inventories & modelling: Singapore

Emissions inventory & modelling
work for the **Singapore National
Environment Agency (NEA)**
working with local consultancy
EnviroSolutions & Consulting

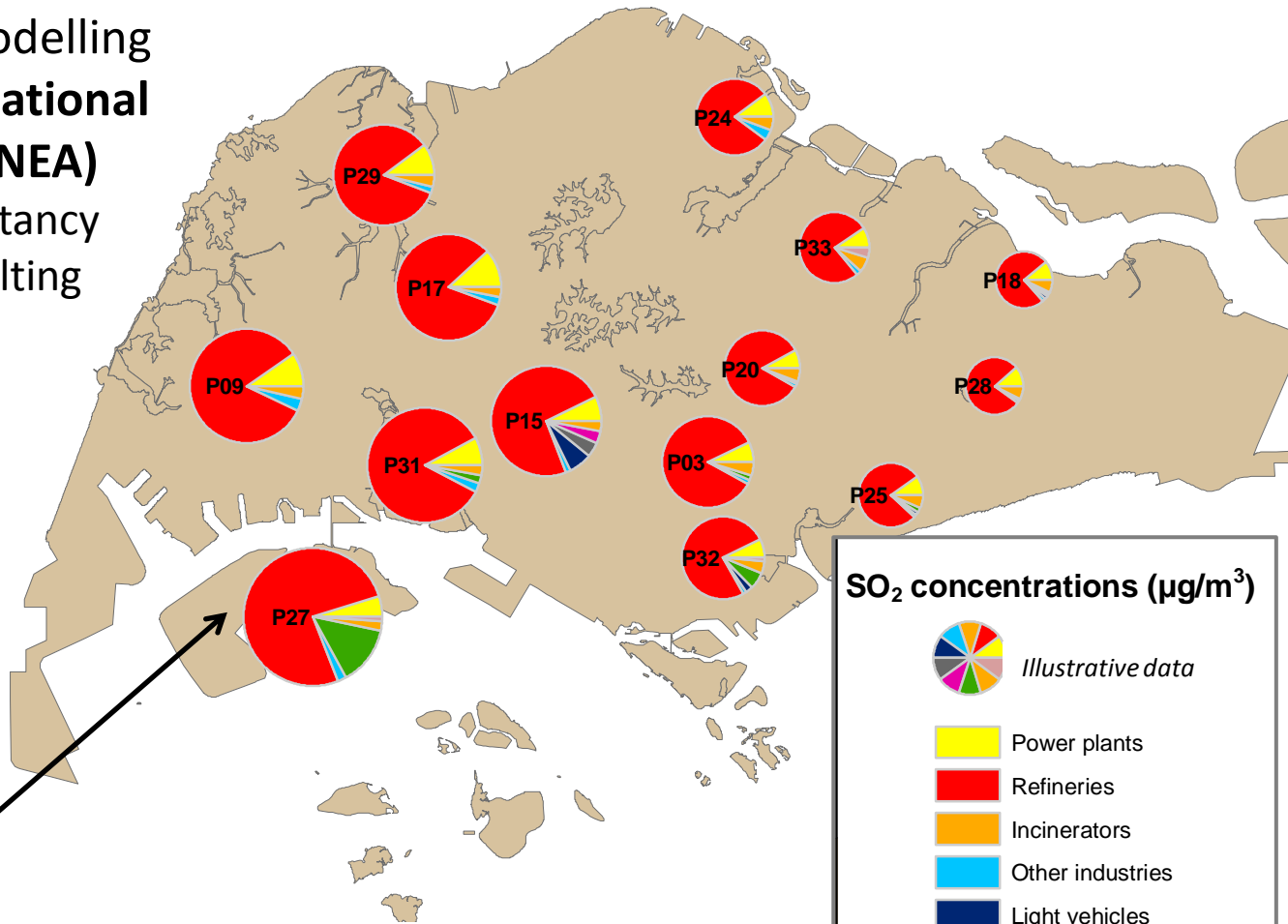
Modelling



*SOURCE
APPORTIONMENT*

Jurong Island : refining,
olefins production and
chemicals manufacturing

The NEA now use **EMIT** and **ADMS-
Urban** to do their own modelling work



SO₂ concentrations (µg/m³)



Illustrative data

- Power plants
- Refineries
- Incinerators
- Other industries
- Light vehicles
- Heavy vehicles
- Motorcycles
- Shipping
- Transboundary
- Other

Emissions inventories & modelling: Singapore

Emissions inventory & modelling
work for the **Singapore National
Environment Agency (NEA)**
working with local consultancy
EnviroSolutions & Consulting

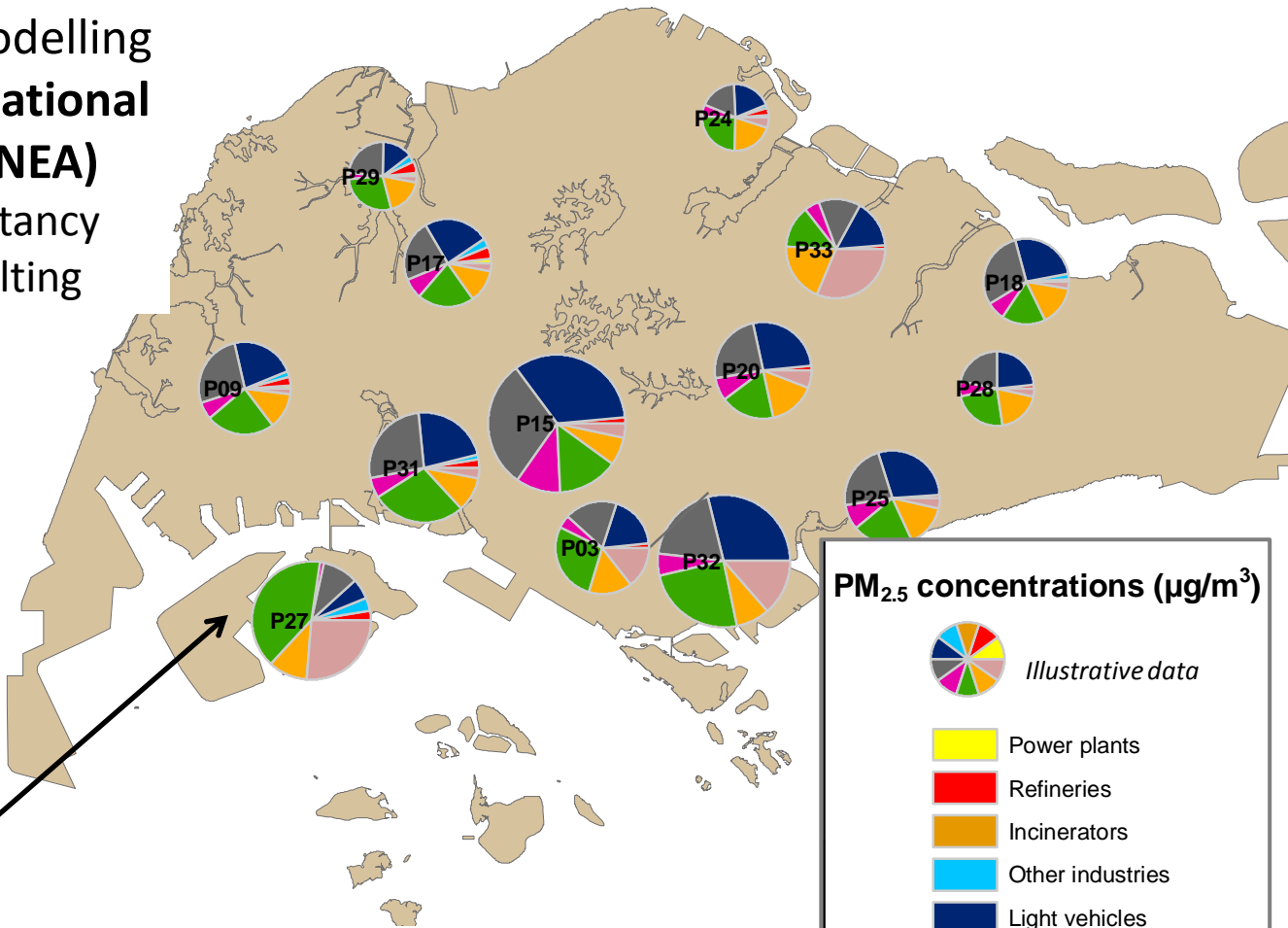
Modelling



*SOURCE
APPORTIONMENT*

Jurong Island : refining,
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The NEA now use **EMIT** and **ADMS-
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Regional to local modelling: UK

West Midlands Air Quality Improvement Programme (WM-Air)

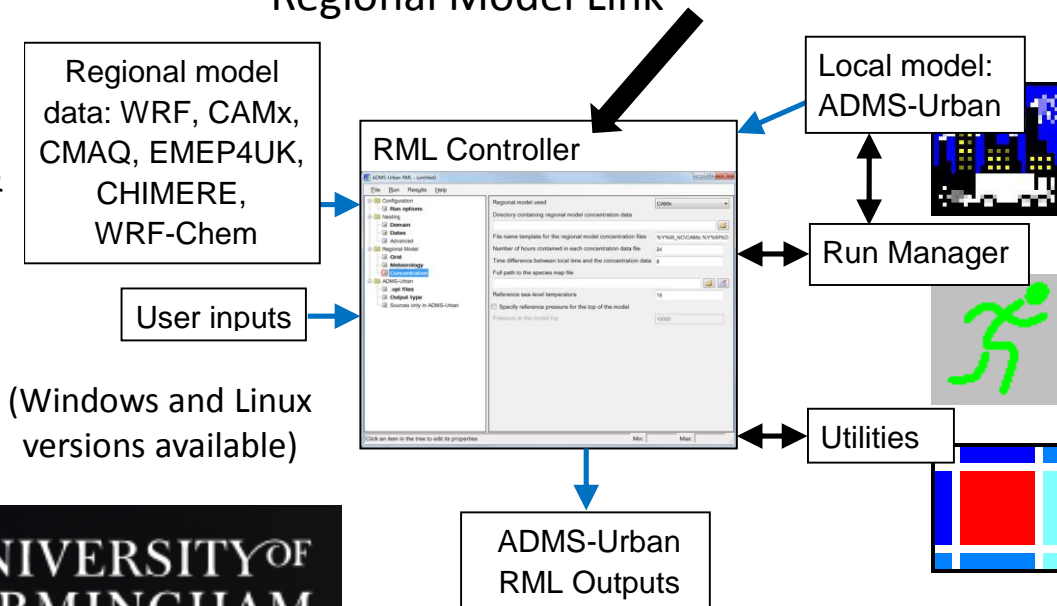


**Working with School of Geography,
Earth and Environmental Sciences,
University of Birmingham**

Project aims:

improve understanding of pollution sources & concentrations; health and economic consequences; specific case studies (e.g. building and green infrastructure)

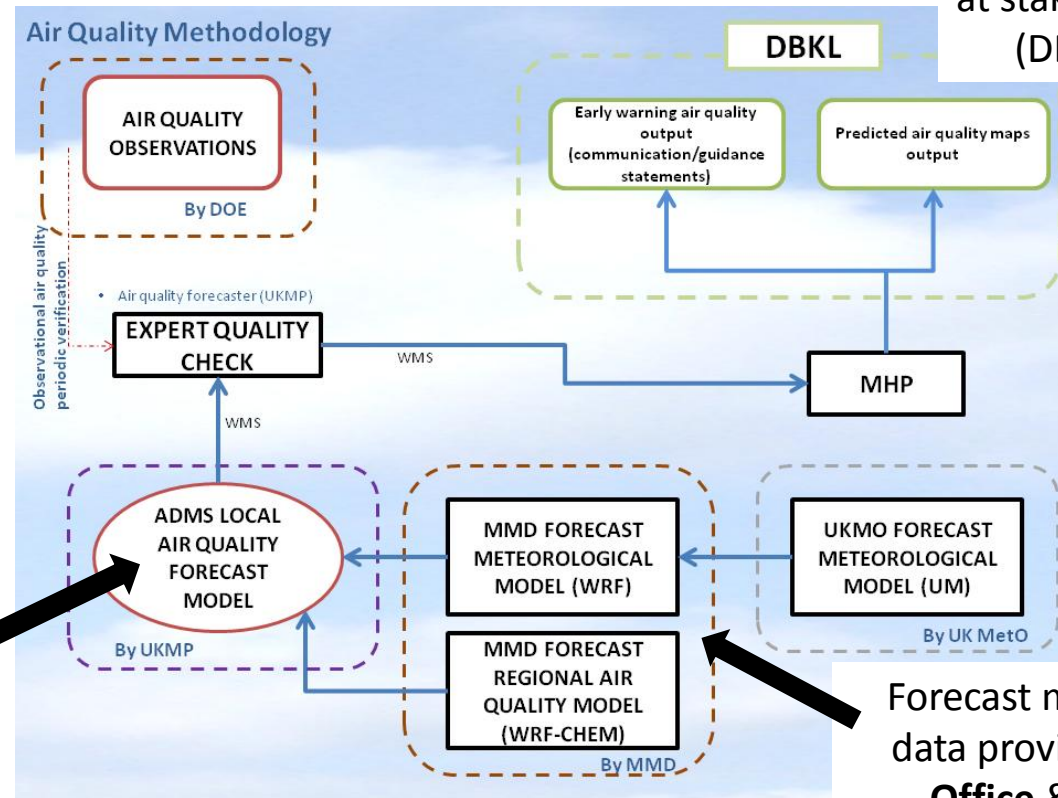
- **Regional-scale (UK, Europe) modelling** : WRF mesoscale meteorological model & CMAQ regional chemistry-transport model.
- **Local-scale (West Midlands, 60 km x 45 km) modelling**: ADMS-Urban
- **Coupled system**: ADMS-Urban Regional Model Link



Disaster Resilient Cities: Forecasting Local Level Climate Extremes & Physical Hazards for Kuala Lumpur

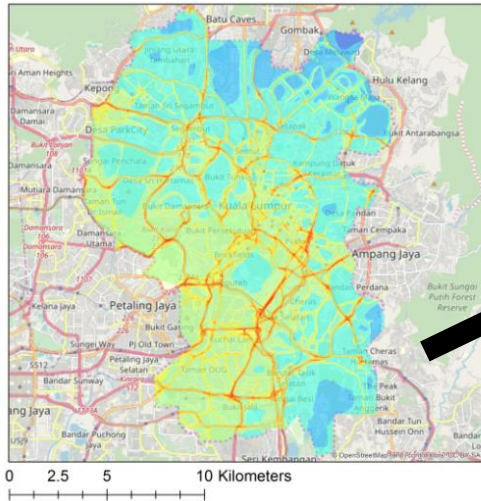
Multi-Hazard platform
at stakeholders' offices
(DBKL, City Hall)

**UK and Malaysian research
& industry collaboration
project** : University of
Kebangsaan Malaysia,
University of Cambridge,
University College London...



Forecast meteorological data providers: **UK Met Office** & Malaysian

Meteorological Department



Innovate UK
CERC

MIGHT
Malaysian Industry-Government Group
for High Technology



Newton-Ungku Omar
Fund



Bahrain/UK Bilateral **SCIENCE** Forum, 6-7 Feb 2019, Bahrain

Summary of CERC projects using ADMS near Bahrain

Countries

Middle East (Kuwait,
Iran, Saudi Arabia)

North Africa (Egypt,
Algeria)

Caucasus (Azerbaijan,
Georgia)

Clients

BP

ADL

Jacobs

Worley Parsons

Projects

Petroleum industry
releases

Power plant stacks

Flare stacks

Gas processing plants

Visible plumes

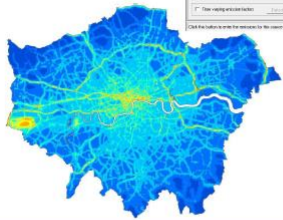
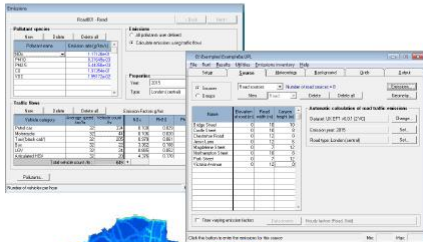
Summary: CERC Software

- All CERC software products are available to licence on an annual or permanent basis for commercial or academic use:
 - ADMS-Urban – for detailed local street-scale modelling
 - ADMS-Urban RML – for linking local with regional modelling
 - ADMS 5 – for detailed industrial modelling
 - EMIT – for compiling detailed local emissions inventories
 - ADMS-Forecast – for running operational air quality forecasts
- www.cerc.co.uk/environmental-software.html

Summary: Software training and support



ADMS-Urban
Urban Air Quality
Management System
Version 4.0



User Guide

CERC

Cambridge Environmental Research Consultants
Environmental Software and Services

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You are here

Welcome to the user area

[Overview](#)[Newsletters](#)[Helpdesk notes](#)[Downloads](#)[Helpdesk](#)[Log out](#)

These pages are intended for CERC model users. They complement the information obtained through model installations and other sections of this website such as the [Environmental software](#) and [Software support](#) sections.

The pages provide you with:

- **Newsletters:** a collection of our latest and previous issues of ADMS, ADMS-Urban and ADMS-Roads newsletters.
- **Helpdesk notes:** a source of information for help in using the models and how to achieve unusual runs.
- **Downloads:** various files available for download, such as utility upgrades, example files, user group meeting presentations etc.
- **Helpdesk:** details of how to contact the Helpdesk service.

help@cerc.co.uk



Training

Scheduled and customised courses,
on site or at CERC's Cambridge office

CERC

Bahrain/UK Bilateral Air Quality Forum, 6-7 Feb 2019, Bahrain

Summary

- High-quality measurements are very important
- Air quality modelling adds value to measurement data: e.g. high spatial resolution, test mitigation scenarios, predict future pollution levels
- CERC's ADMS models represent the state-of-the-art
 - used internationally by academics, consultants and local and national government agencies
- CERC has extensive air quality modelling experience
 - collaborate with academic, commercial and governmental partners internationally

Thank you for your attention