

# Dispersion Modelling Tools for Urban Air Quality and Climate

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Albania: Architecture, Public Health & Urban Renaissance Symposium

28<sup>th</sup> April 2016

London



# CERC Software

	ADMS 5	<ul style="list-style-type: none"><li>• Models dispersion of industrial emissions for permit applications and environmental impact assessments</li></ul>
	ADMS-Urban	<ul style="list-style-type: none"><li>• Comprehensive street-scale modelling system for managing urban air quality for planning and air quality assessments.</li></ul>
	ADMS-Roads	<ul style="list-style-type: none"><li>• Simplified version of ADMS-Urban for modelling road traffic and some industrial sources</li></ul>
	ADMS-Airport	<ul style="list-style-type: none"><li>• Extension of ADMS-Urban for managing air quality at airports</li></ul>
	EMIT	<ul style="list-style-type: none"><li>• Emissions inventory database software for toxic emissions and greenhouse gases</li></ul>
	FLOWSTAR-Energy	<ul style="list-style-type: none"><li>• Model of wind energy and airflow at high spatial resolution for wind farm planning and other airflow-related applications</li></ul>
	ADMSSTAR	<ul style="list-style-type: none"><li>• Advanced software for modelling short-term accidental releases</li></ul>
	ADMS-Screen	<ul style="list-style-type: none"><li>• Simple single source screening model for industrial emissions</li></ul>
	GASTAR	<ul style="list-style-type: none"><li>• Dense gas dispersion model</li></ul>
	Run Manager	<ul style="list-style-type: none"><li>• Software for distributing CERC model runs across networks</li></ul>
	ADMS Temperature and Humidity Model	<ul style="list-style-type: none"><li>• Local climate model suitable for assessing land-use impact on ambient temperatures</li></ul>

# Overview of presentation

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Air pollution dispersion modelling in Urban areas: ADMS-Urban

Air quality forecasting: the London *airTEXT* service

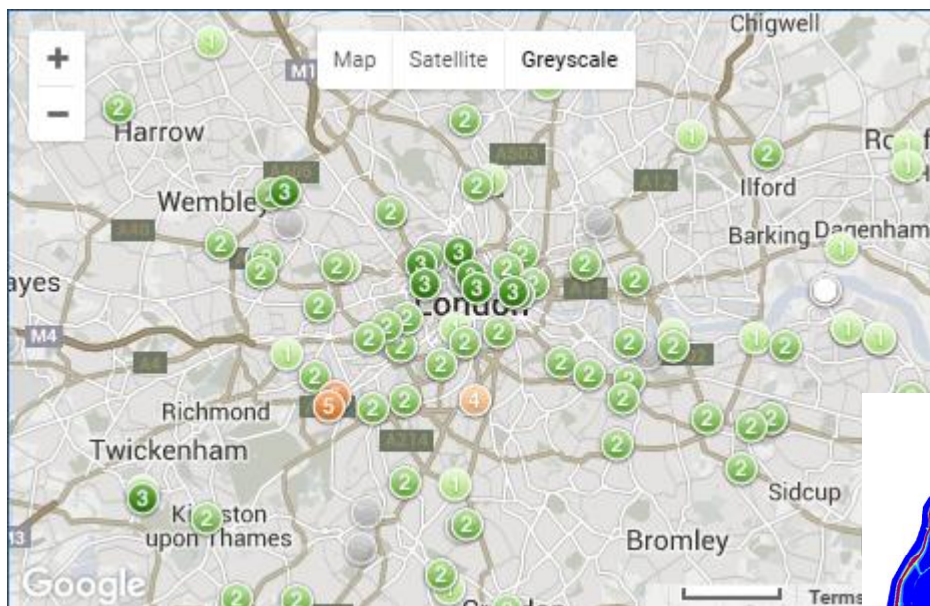
Urban climate modelling: the ADMS Temperature and Humidity Model

# Air quality and health

- World Health Organisation (March 2014):
  - *‘Air pollution is a major environmental risk to health. By reducing air pollution levels, countries can reduce the burden of disease from stroke, heart disease, lung cancer, and both chronic and acute respiratory diseases, including asthma.’*
  - *‘Ambient (outdoor air pollution) in both cities and rural areas was estimated to cause 3.7 million premature deaths worldwide in 2012.’*
- Public Health England (April 2014):
  - *‘Current levels of particulate air pollution have a considerable impact on public health. Measures to reduce levels of particulate air pollution, or to reduce exposure of the population to such pollution, are regarded as an important public health initiative.’*
- WHO Guidelines, EU Air quality Standards and UK National Air Quality Objectives are in place to protect the public from unsafe levels of air pollution.
- Mainly due to road traffic, industry and domestic heating, the main pollutants of concern in European cities are:
  - PM<sub>10</sub> (particles smaller than 10 microns),
  - PM<sub>2.5</sub> (particles smaller than 2.5 microns),
  - NO<sub>2</sub>, and
  - ozone (a secondary pollutant formed by photolysis of NO<sub>2</sub>)

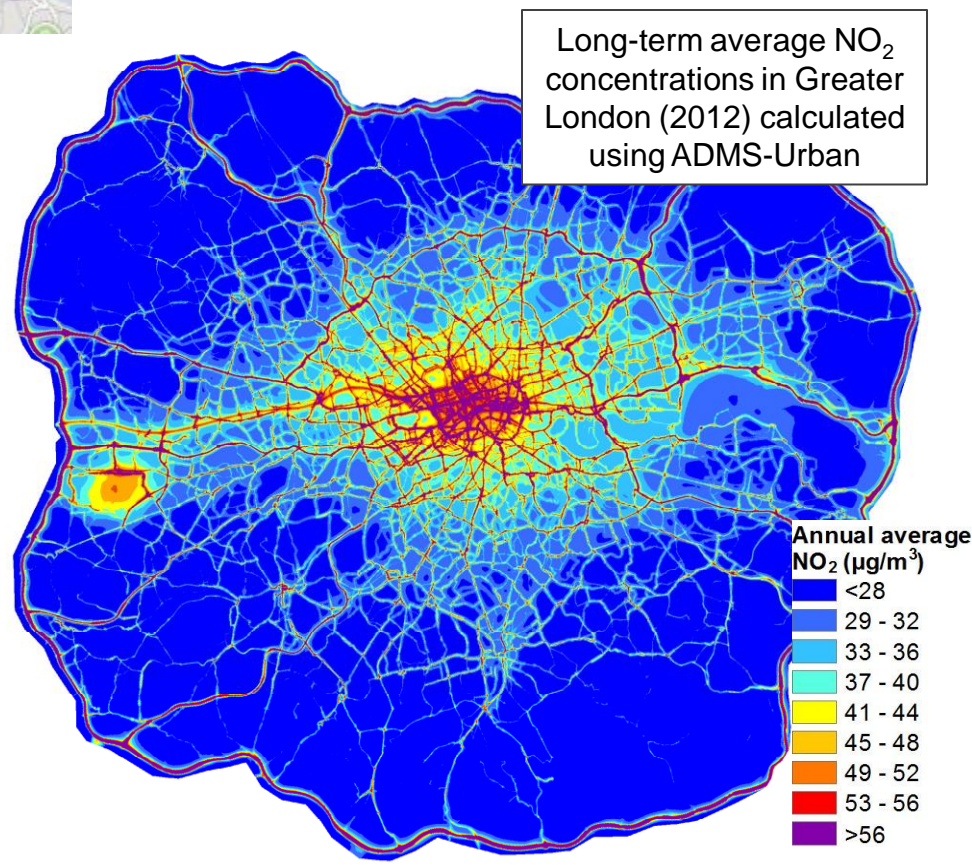


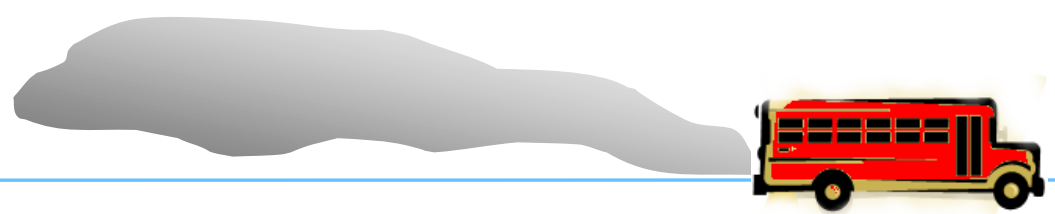
# Assessing urban air quality: why dispersion models?



Air pollution monitors provide essential information about historical and current levels, but they do not give the whole picture and they can not predict the future.

Dispersion models like CERC's ADMS-Urban dispersion modelling system can map air quality at fine resolution over whole cities, test the effectiveness of emissions reduction measures and help cities plan for cleaner air.





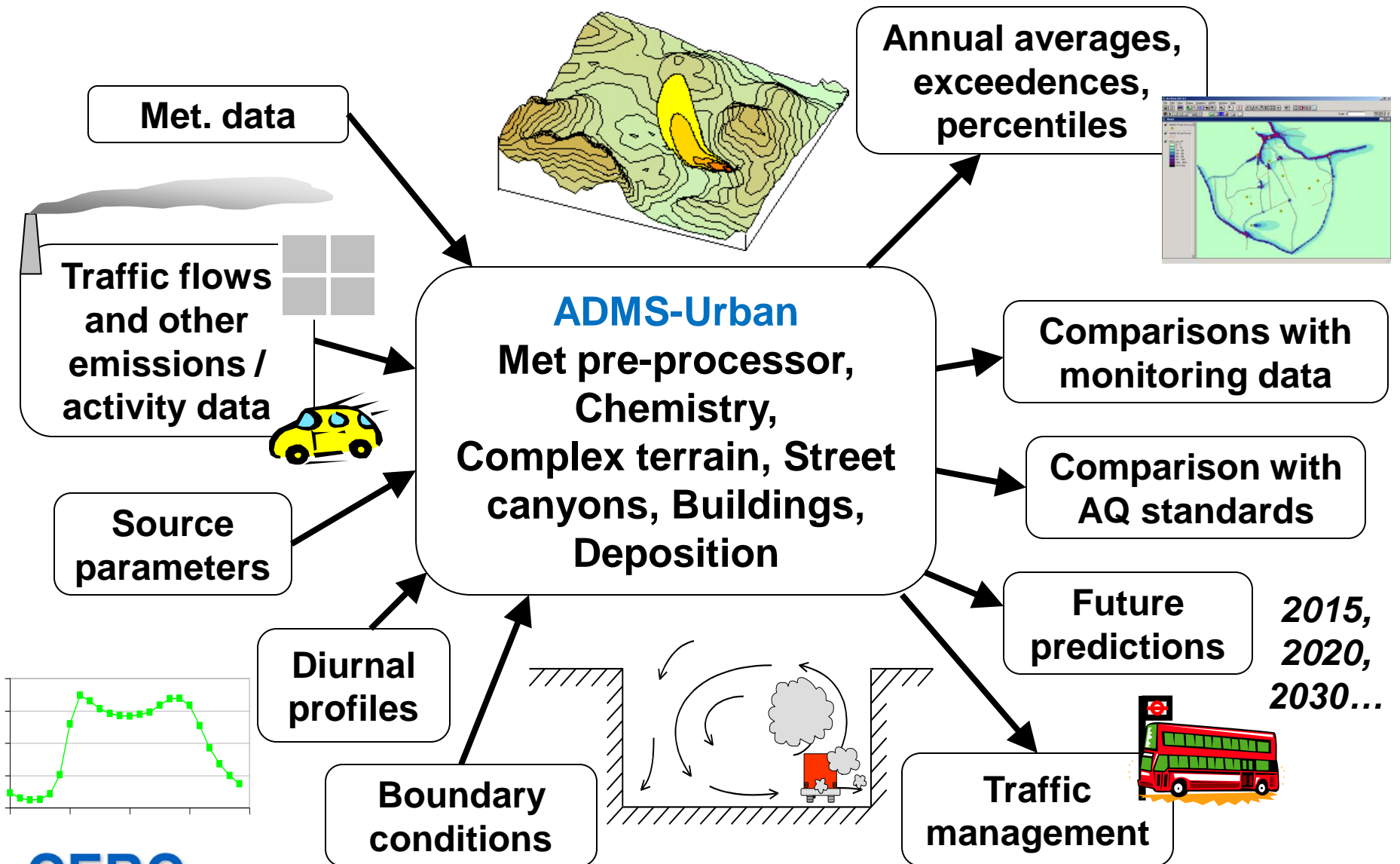
## What influences the resultant concentration due to the emissions from a particular vehicle?

<b>Meteorological conditions</b>	Wind speed and direction and ambient temperature influence where the emissions are dispersed
<b>Vehicle speed and size</b>	Vehicles create turbulence, which influences dispersion
<b>Road geometry</b>	Street canyons lead to re-circulation of emissions and consequently high concentrations
<b>Exhaust heights and temperatures</b>	The initial location and buoyancy of the emission influence dispersion
<b>Sunlight</b>	Some pollutants take part in fast chemical reactions that are triggered by sunlight
<b>Concentration levels</b>	The fast chemical reactions are dependent on the concentrations of several pollutants, for example ozone

The relationship between emissions and concentrations is therefore non-linear.

# Dispersion modelling

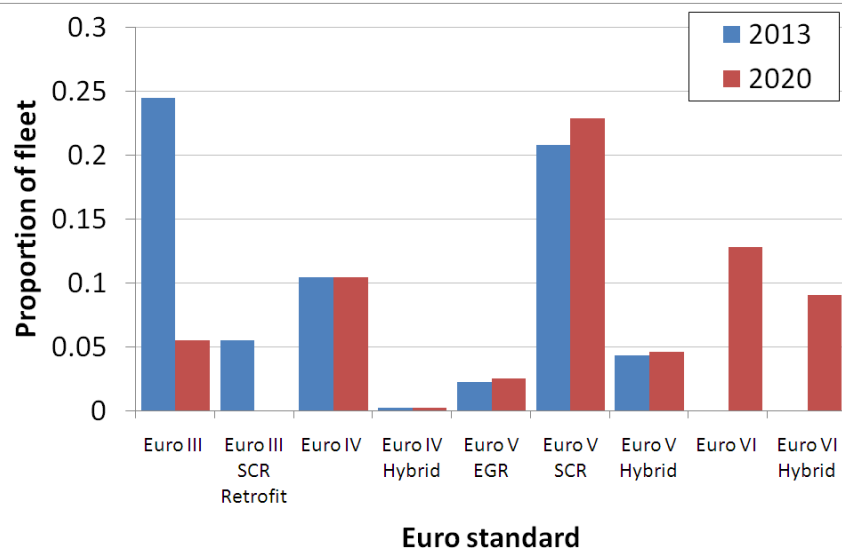
## Introduction



# EMIT: Emissions calculations

## Detailed fleet calculations

- **Full** emissions inventory held in EMIT 3.2 i.e. road and
- Detailed emissions calculations can be performed



Vehicle sub-category	Vehicle sub-category description
R212	Diesel Bus (15-18 tonnes) Euro II
R212a	Diesel Bus (15-18 tonnes) Euro II Particle Trap
R213	Diesel Bus (15-18 tonnes) Euro III
R213a	Diesel Bus (15-18 tonnes) Euro III Particle Trap
R213d	Diesel Bus (15-18 tonnes) Euro III Particle Trap SCR
R214	Diesel Bus (15-18 tonnes) Euro IV
R214b	Diesel Bus (15-18 tonnes) Euro IV Hybrid
R215	Diesel Bus (15-18 tonnes) Euro V
R215b	Diesel Bus (15-18 tonnes) Euro V Hybrid
R215e	Diesel Bus (15-18 tonnes) Euro V EGR



Road fleet data for Route Type: NAEI 12 LAEI oth U13, Emission Factors: NAEI 2012 U...

Vehicle sub-category	Buses and coaches	Rigid HGVs 2 axles	Rigid HGVs 3 axles	Ri
R208e	0.990405	0	0	
R208g	0.009361	0	0	
R209	0	0	0	
R209b	0	0	0	
R210	0	0	0	
R211	0	0	0	
R212	0	0	0	
R212a	0	0	0	
R213	0	0	0	
R213a	19.590452	0	0	
R213d	4.467587	0	0	
R214	8.415633	0	0	
R214b	0.215305	0	0	
R215	16.656213	0	0	
R215b	3.159373	0	0	
R215e	1.85069	0	0	
R215g	0.351041	0	0	
R216	0	0	0	
R216b	0	0	0	
R217	0	0	0	
R218	0	0	0	

Close Cancel Apply Copy Paste Adjust

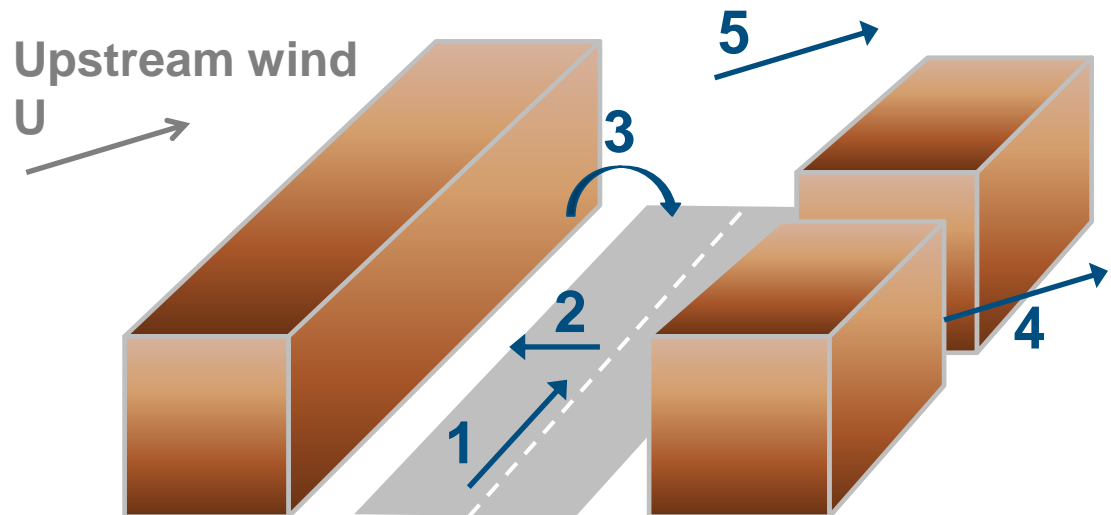
Edit traffic composition data



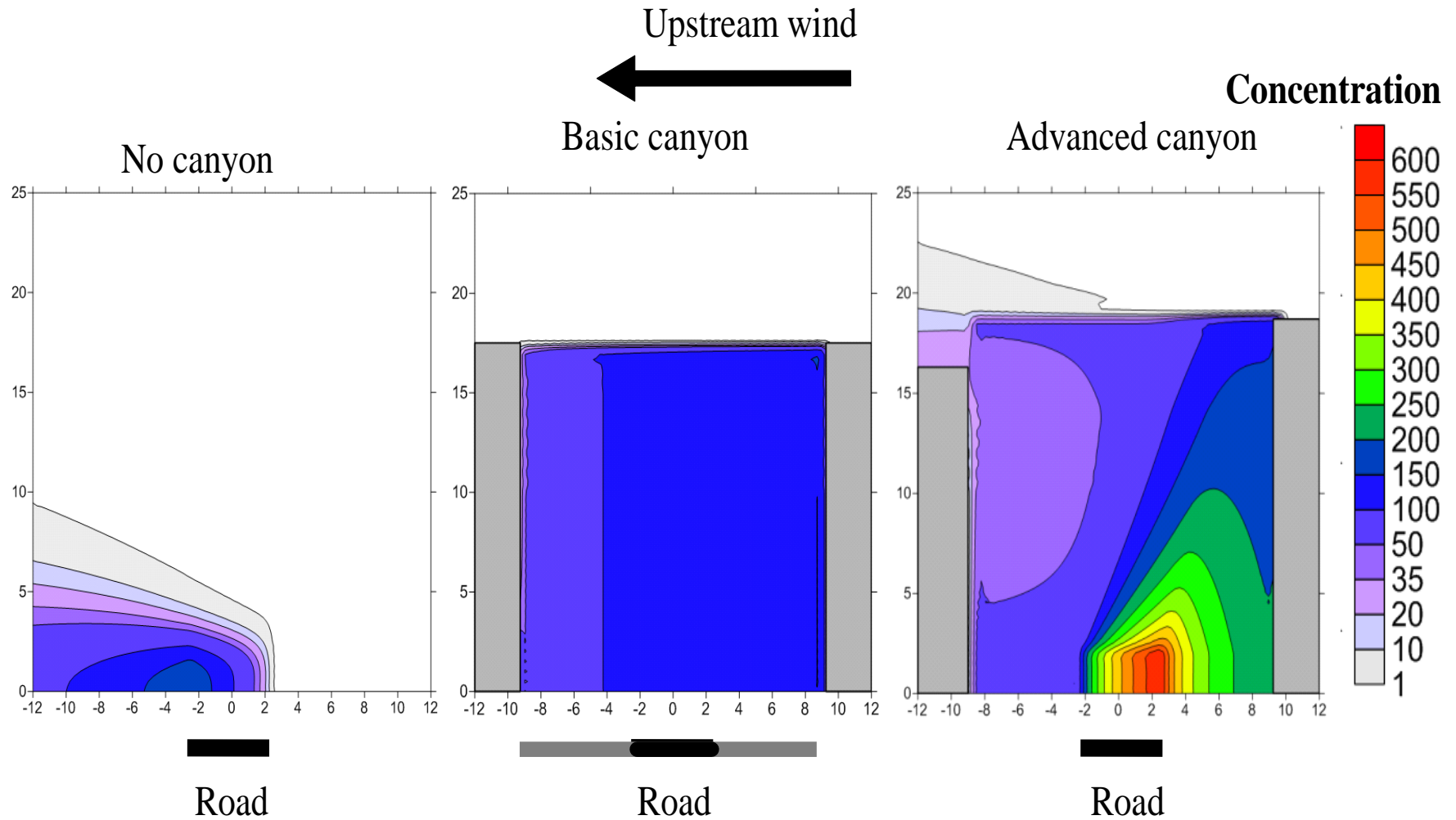
# ADMS-Urban: street canyons



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**

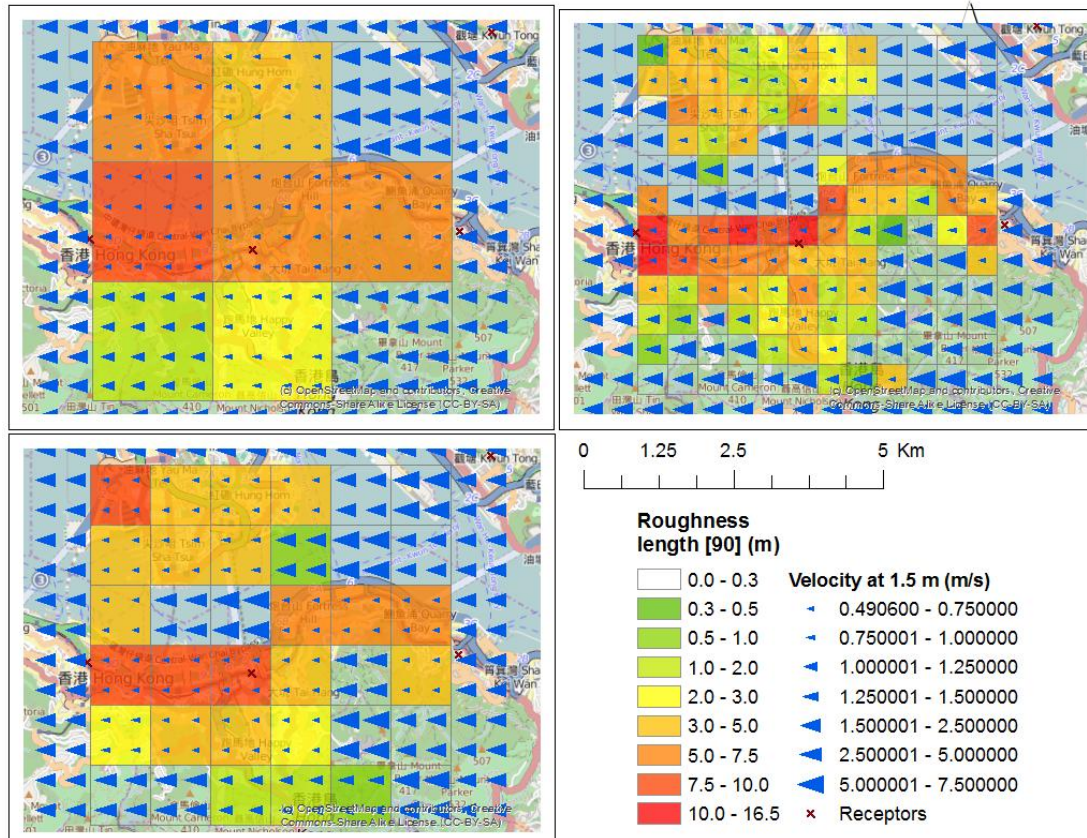


# ADMS-Urban: street canyons



# ADMS-Urban: urban canopy air flow

High building densities result in a reduction in wind speed, leading to a build up of pollutant concentrations.



1.5 m wind speed variations in central Hong Kong, as calculated by the ADMS Urban Canopy flow module at 2 km, 1 km and 500 m resolution; results are for one hour with the wind direction from the east.



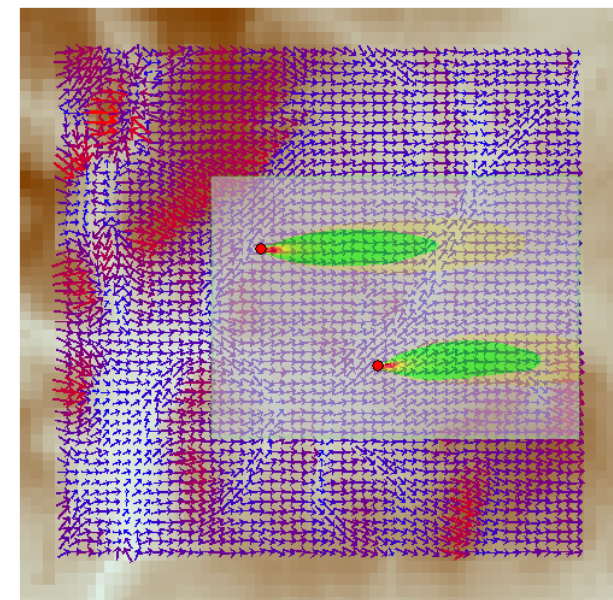
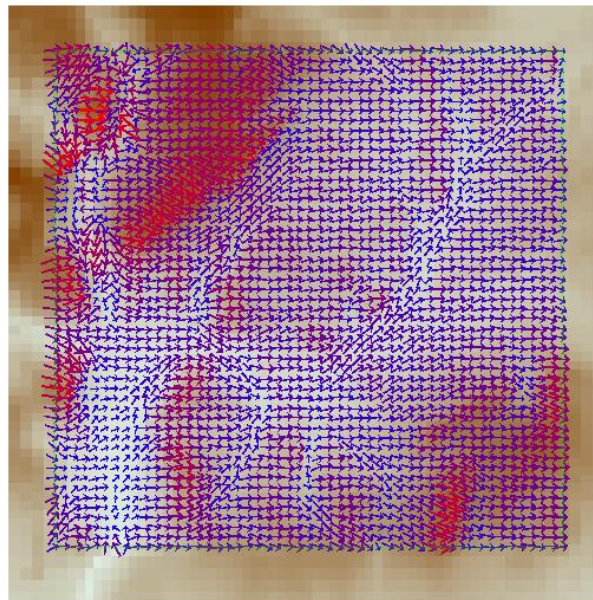
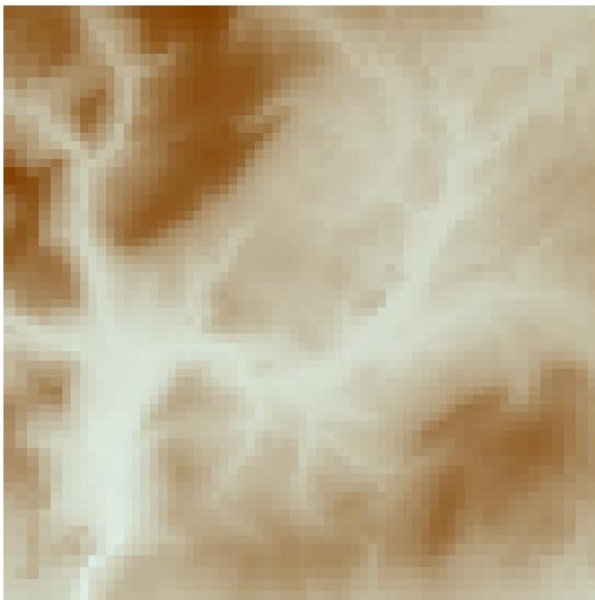
# ADMS-Urban: complex terrain

FLOWSTAR

Takes terrain and/or  
surface roughness data

Calculates flow field

Calculated flow field  
affects plume trajectory  
and plume spread





# Linking ADMS-Urban with regional models: RML

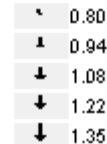
- Regional to local meteorology

**WRF output over London**  
5 km grid resolution

Mean flow (m/s)

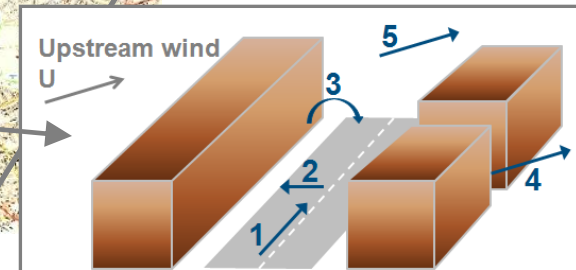


Local flow (m/s)



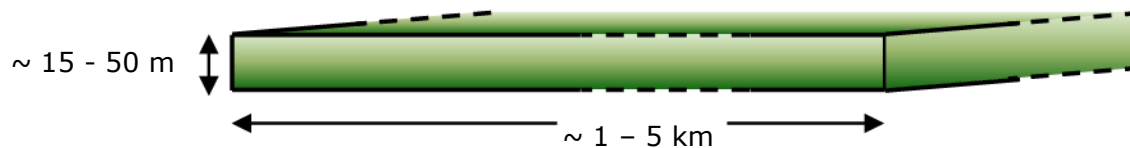
**ADMS-Urban 'urban canopy'**  
1 km grid resolution

**ADMS-Urban 'advanced canyon'**  
street-scale resolution



- Regional to local emissions

*Typical regional model grid cell (lowest layer)*

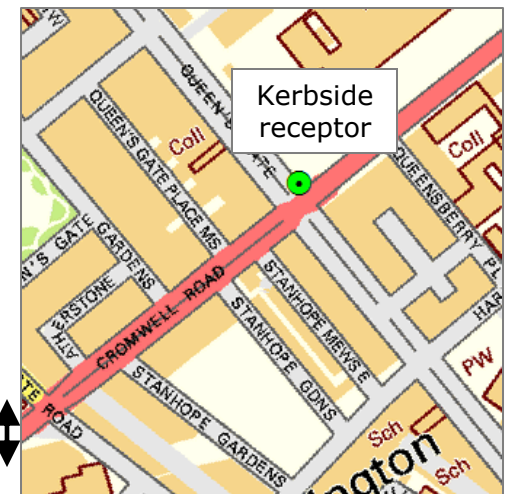


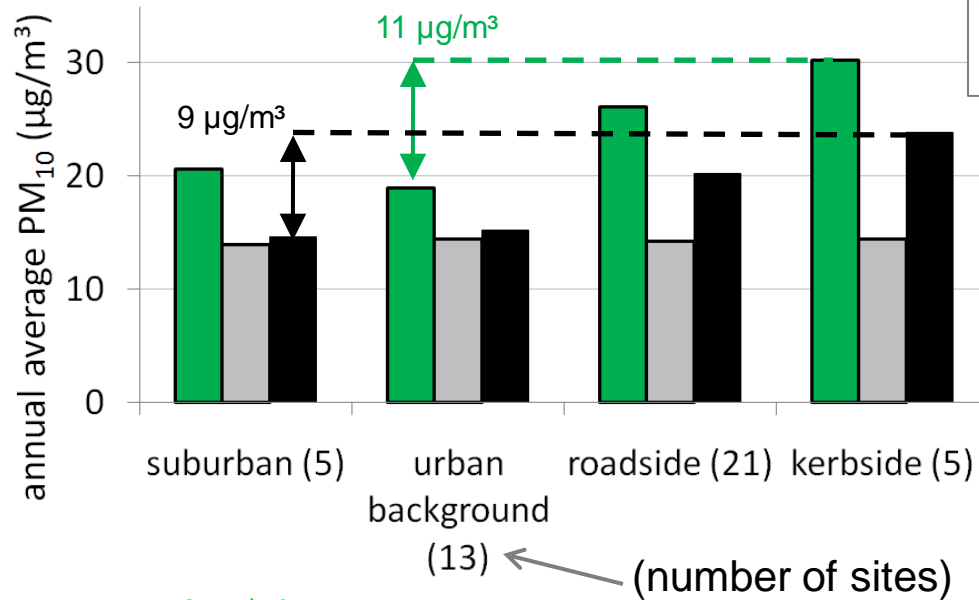
- Source dimensions << regional model grid scale
- Local model explicitly represents source dimensions



Vehicle heights  
~ 1.5 - 5 m

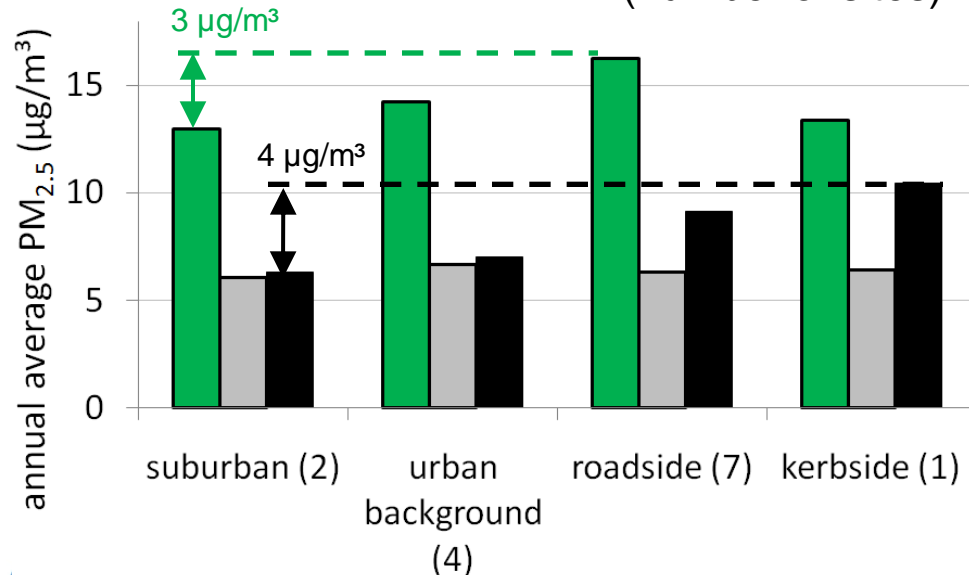
Road widths  
~ 6 - 50 m





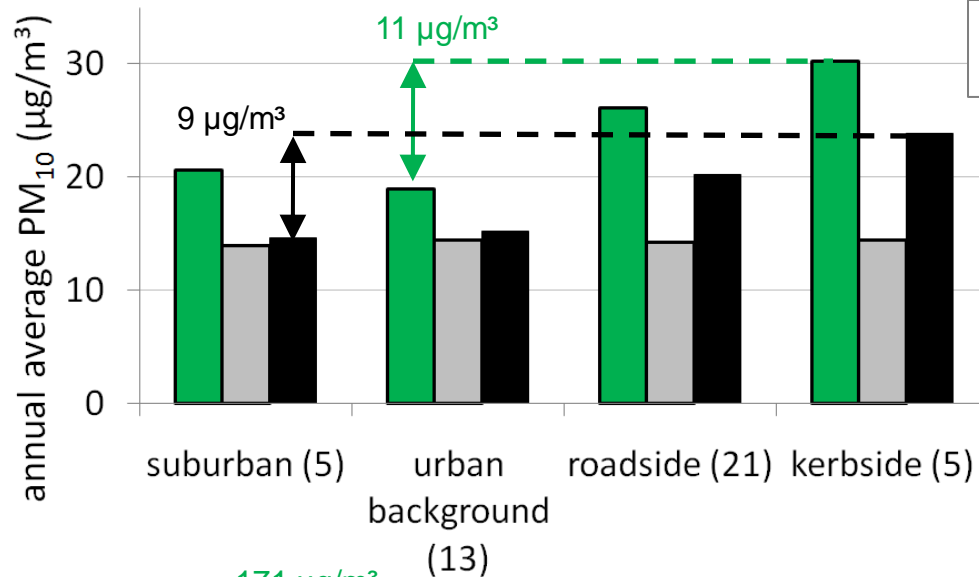
$PM_{10}$

- Long-range transport important
- Maximum urban increment:
  - Measured ~  $11 \mu g/m^3$
  - Modelled ~  $9 \mu g/m^3$



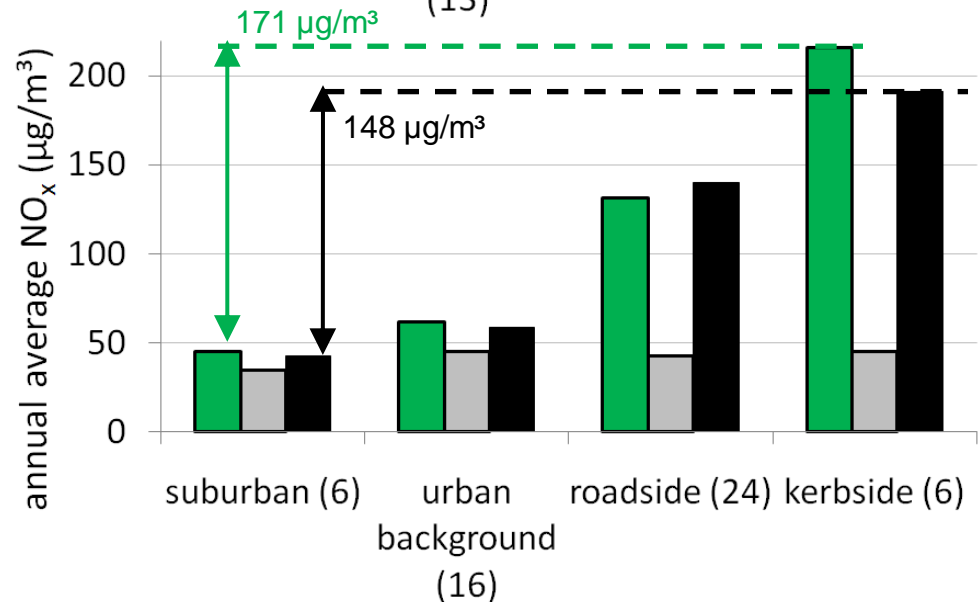
$PM_{2.5}$

- Long-range transport important
- Maximum urban increment:
  - Measured ~  $3 \mu g/m^3$
  - Modelled ~  $4 \mu g/m^3$



$PM_{10}$

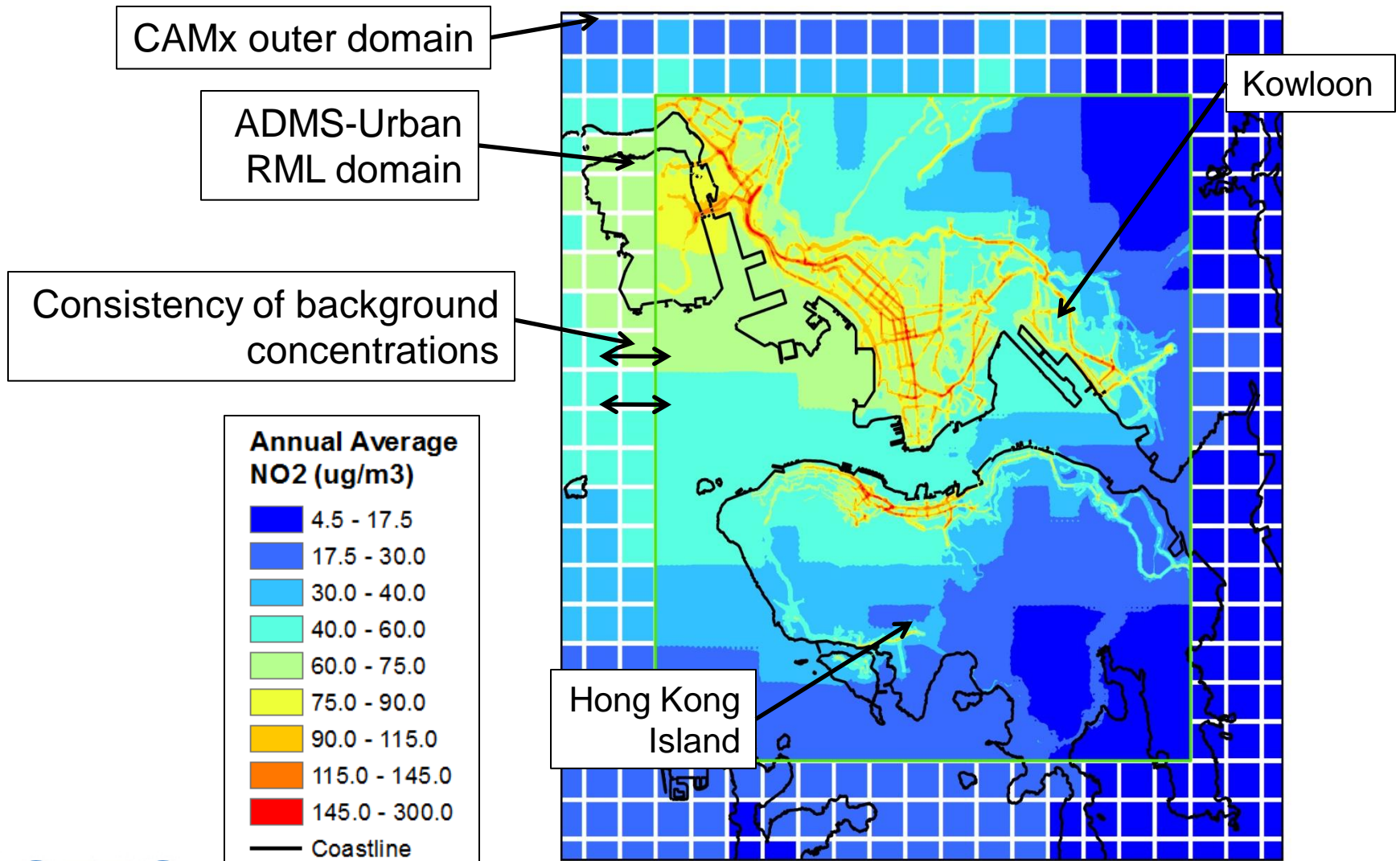
- **Long-range transport important**
- Maximum urban increment:
  - Measured  $\sim 11 \mu g/m^3$
  - Modelled  $\sim 9 \mu g/m^3$



$NO_x$

- **Long-range transport unimportant**
- Maximum urban increment:
  - Measured  $\sim 171 \mu g/m^3$
  - Modelled  $\sim 148 \mu g/m^3$

# Example use of ADMS-Urban RML system

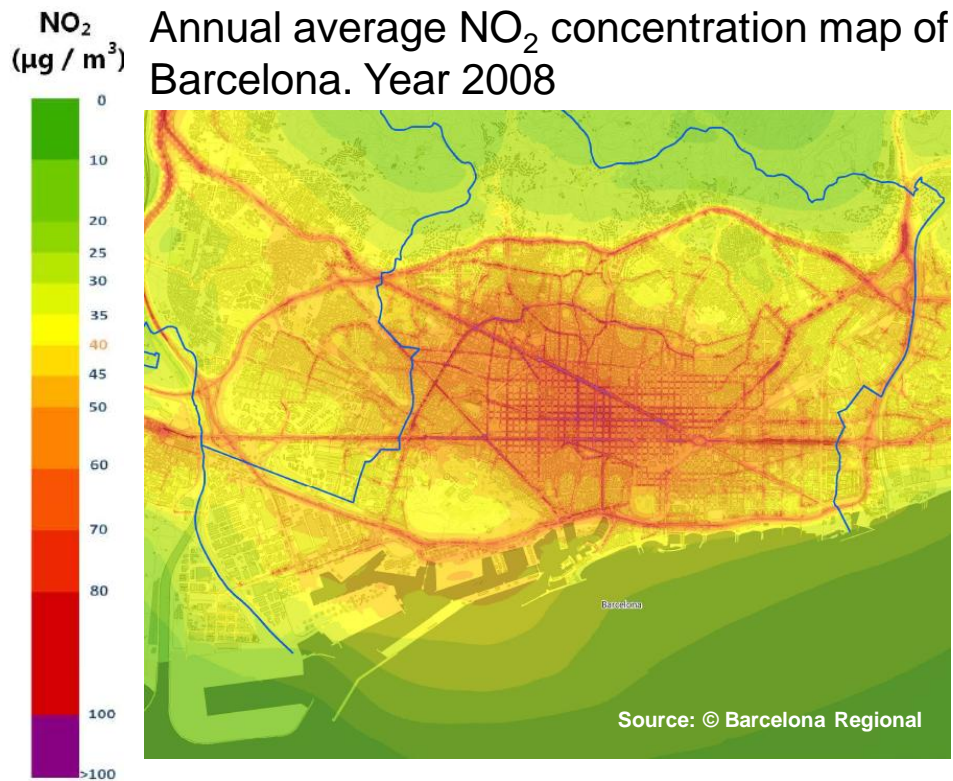




# Other example applications of ADMS-Urban

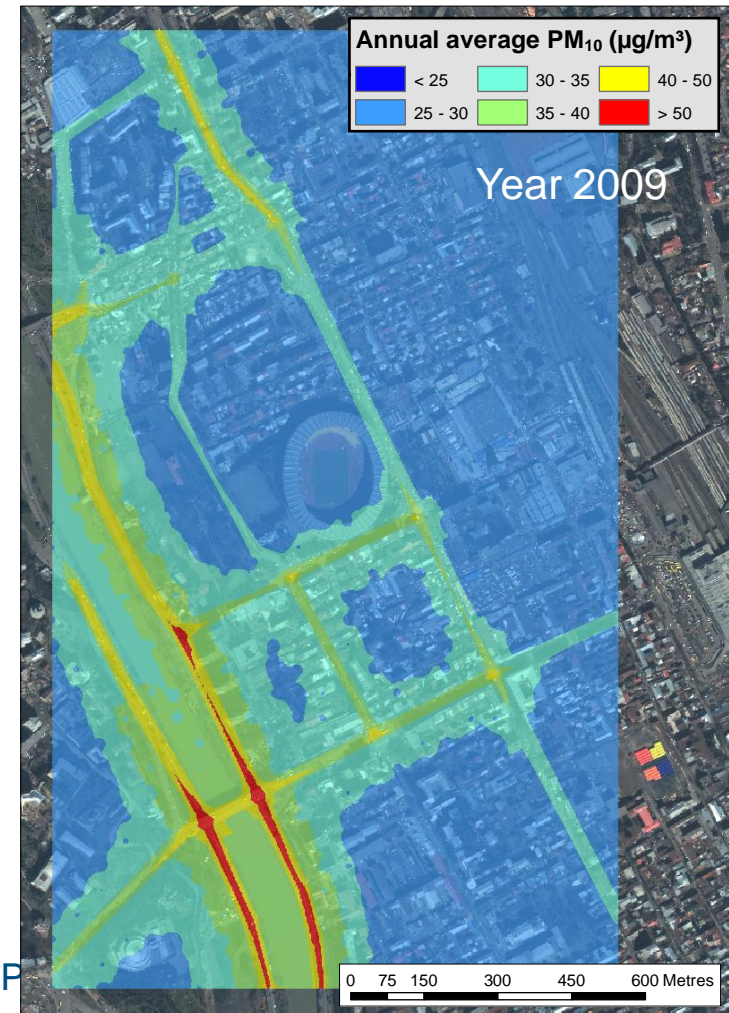
## Barcelona, Spain

Modelling by Barcelona Regional



## Tbilisi, Georgia

Modelling by CERC



Weather  
forecast

Regional air  
quality forecast

Emissions



Pollution forecasts  
expressed using UK Gov's  
Daily Air Quality Index

NO<sub>2</sub>

Ozone

PM<sub>10</sub>

PM<sub>2.5</sub>



Operated by CERC in partnership with GLA, London  
boroughs, Public Health England, Environment Agency

Free air quality alerts to over **15,000** subscribers

Forecast 3 days ahead with 7m resolution

Text, email, voicemail alerts

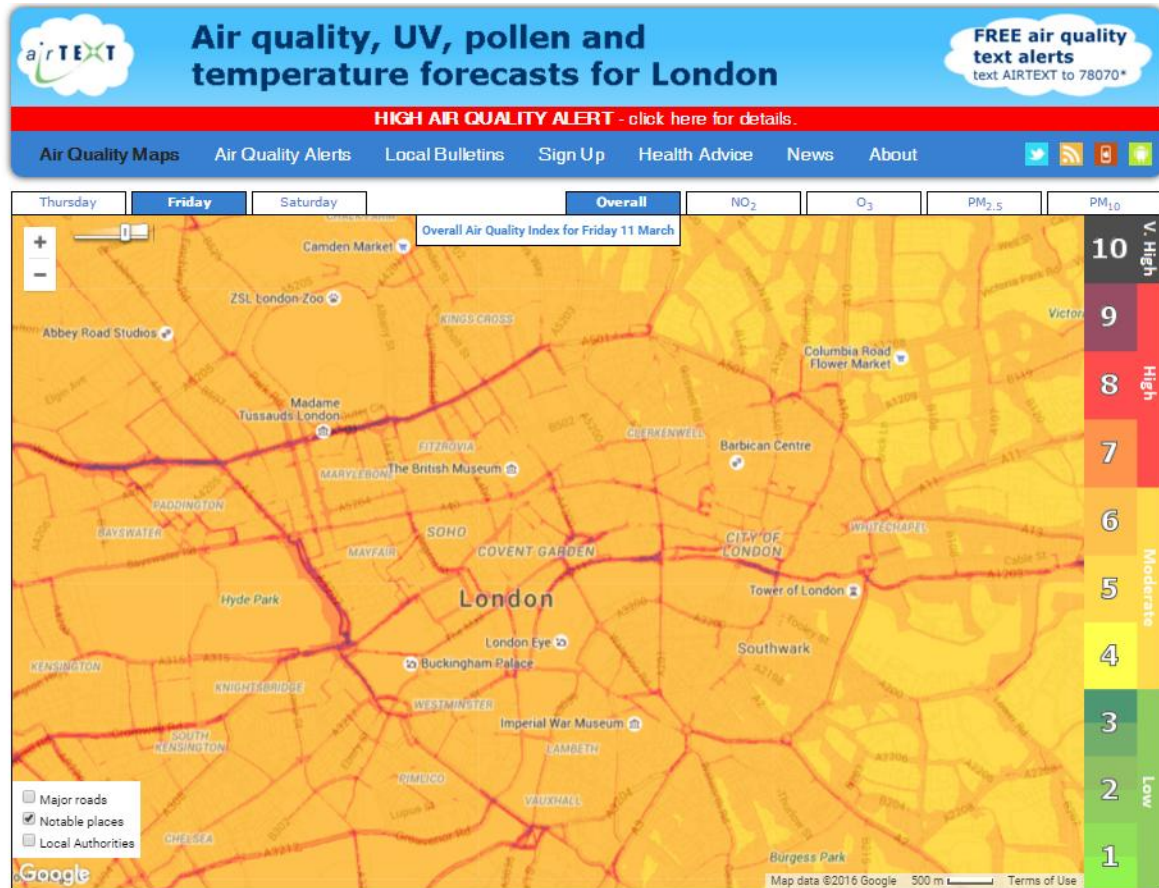
Pollution maps

Smartphone app

Daily health bulletin



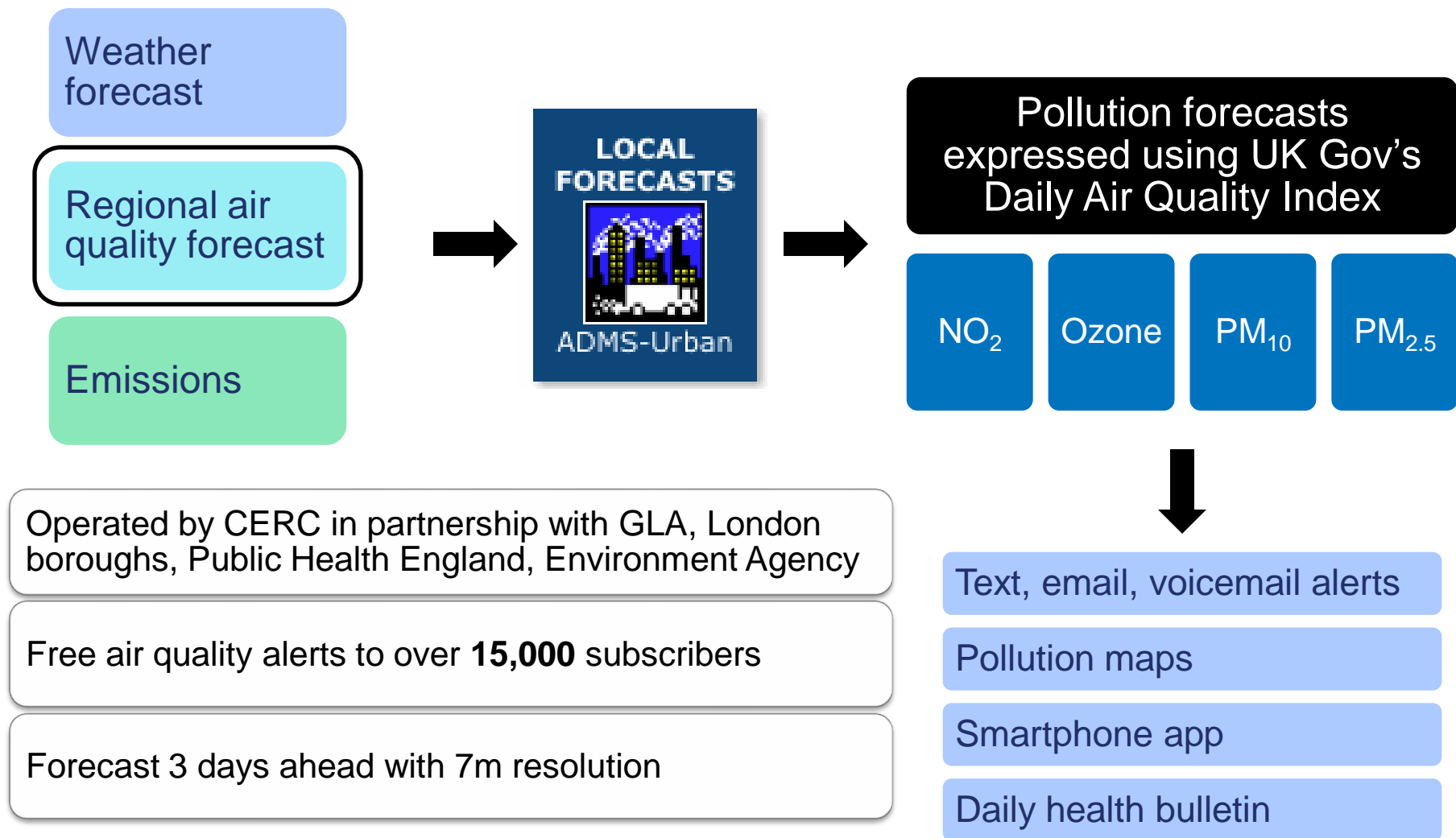
# Air quality forecasts for London



Daily Health Bulletin for City of London Thursday 25th February 2016	
<b>Air pollution</b> <b>MODERATE</b> Action may be required. Health effects are unlikely to require action. If unwell, contact GP. <small>This is a daily air pollution forecast and may be LOW, MODERATE, HIGH or VERY HIGH.</small>	<b>UV Index</b> <b>2 (LOW)</b> No action required. You can safely stay outside. <small>This is a forecast of maximum hourly cloud adjusted solar UV index over a 24-hour period. 1 to 2 is LOW, 3 to 5 is MODERATE, 6 to 7 is HIGH or 8+ is VERY HIGH.</small>
<b>Pollen</b> <b>LOW</b> <small>This is a daily grass pollen forecast and may be LOW, MODERATE, HIGH or VERY HIGH.</small>	<b>Temperature</b> <b>Max. Day 6°C/42°F</b> <b>Min. Night -1°C/30°F</b> <small>These are the minimum and maximum hourly temperatures predicted over a 24-hour period.</small>



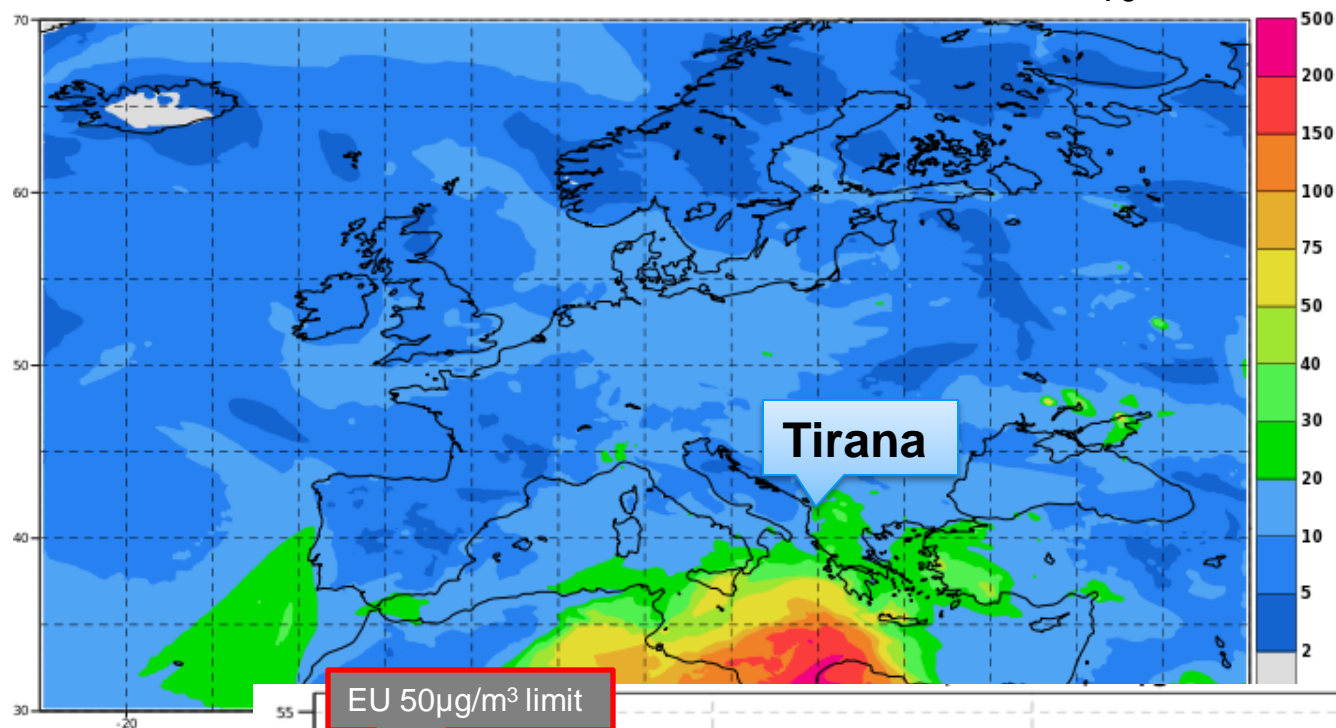






# Regional air quality forecast: EU CAMS

CAMS forecast map for Sat 30<sup>th</sup> April: PM<sub>10</sub> (µg/m<sup>3</sup>)



Covers Europe at 12km resolution

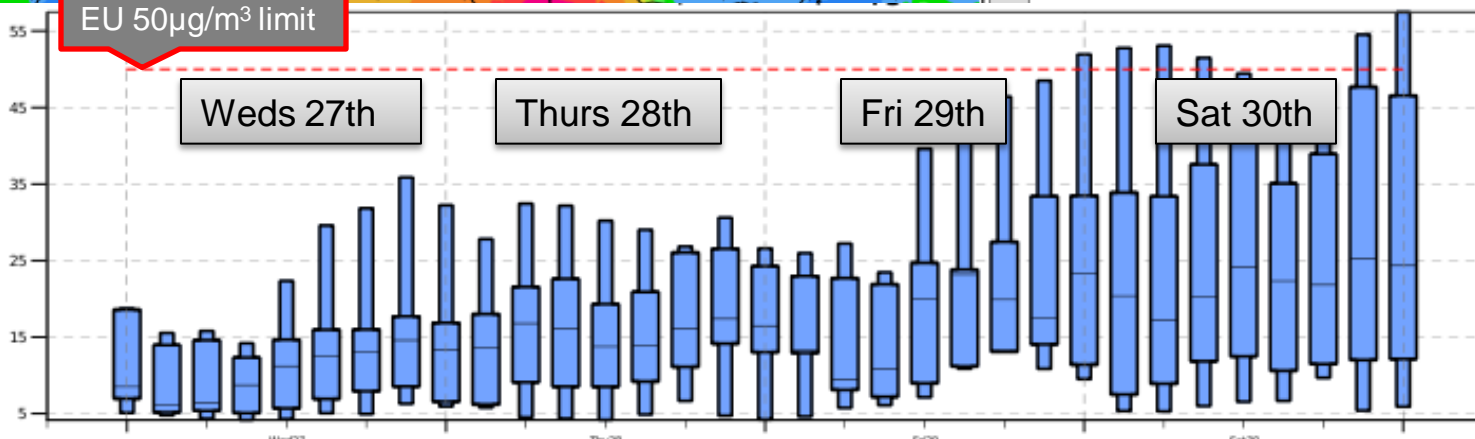
PM<sub>10</sub>, PM<sub>2.5</sub>,  
Ozone, NO<sub>2</sub>, NO<sub>x</sub>

Forecast up to 4 days ahead

Data, maps etc  
freely available

**CAMS**  
PM<sub>10</sub>  
forecast  
for Tirana

**CERC**




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# ADMS Temperature and Humidity model:

## Motivation


Building fabric in an urban area has the capacity to absorb more heat compared to a rural environment



Heat absorbed during the day is re-released at night

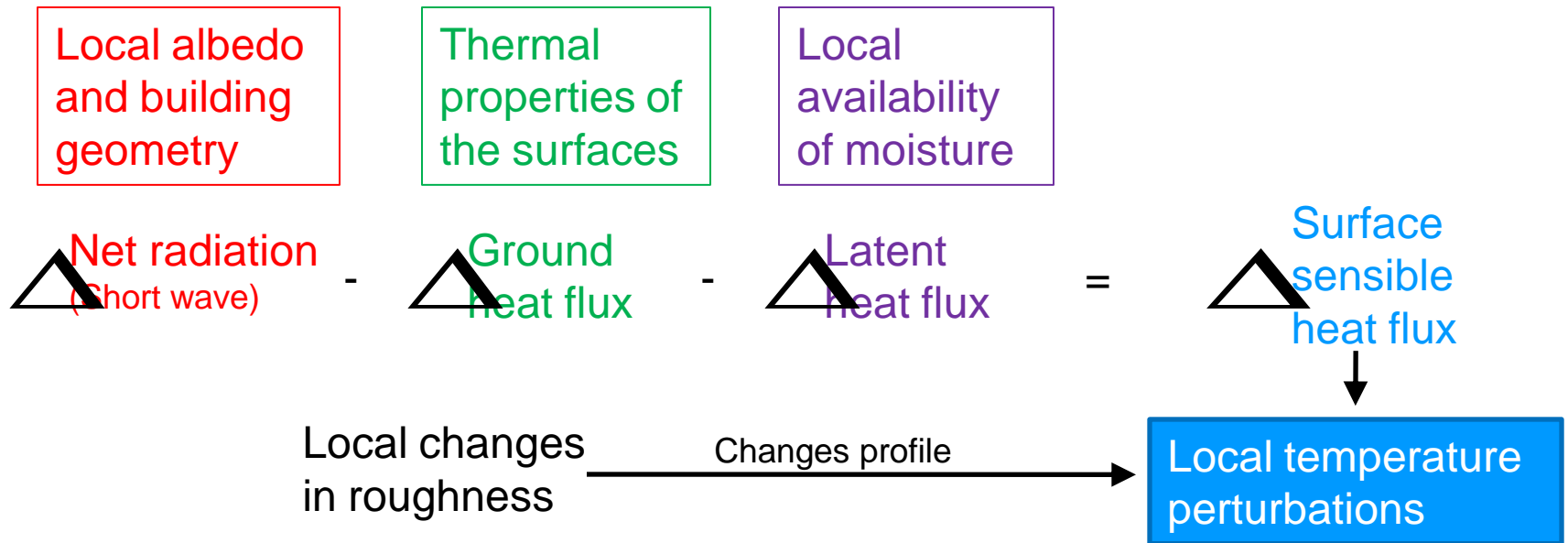
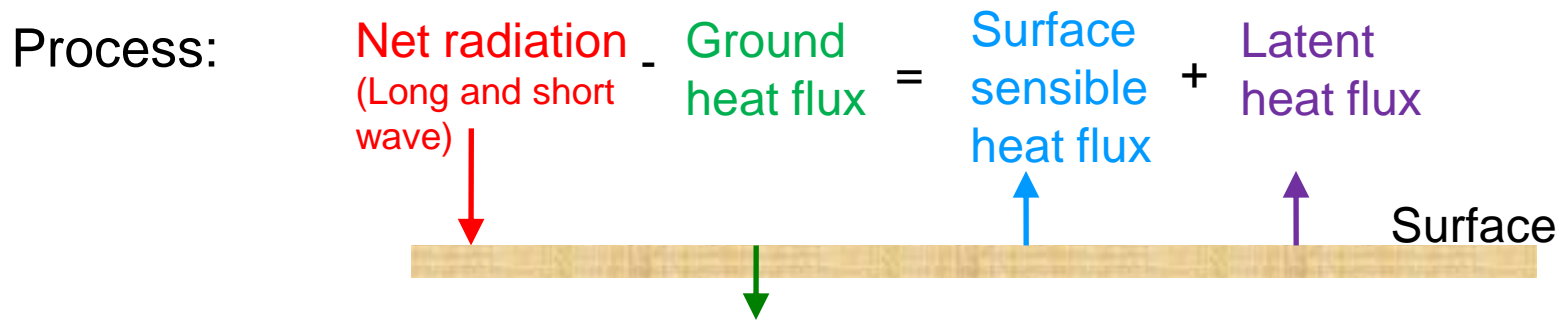


During heatwaves, this means night-time temperatures do not decrease as they would in rural areas



This causes increased mortality; people can cope with increased temperatures during the day if it is cool at night

# ADMS Temperature and Humidity model: Background



# ADMS Temperature and Humidity Model: Parameterising urban datasets

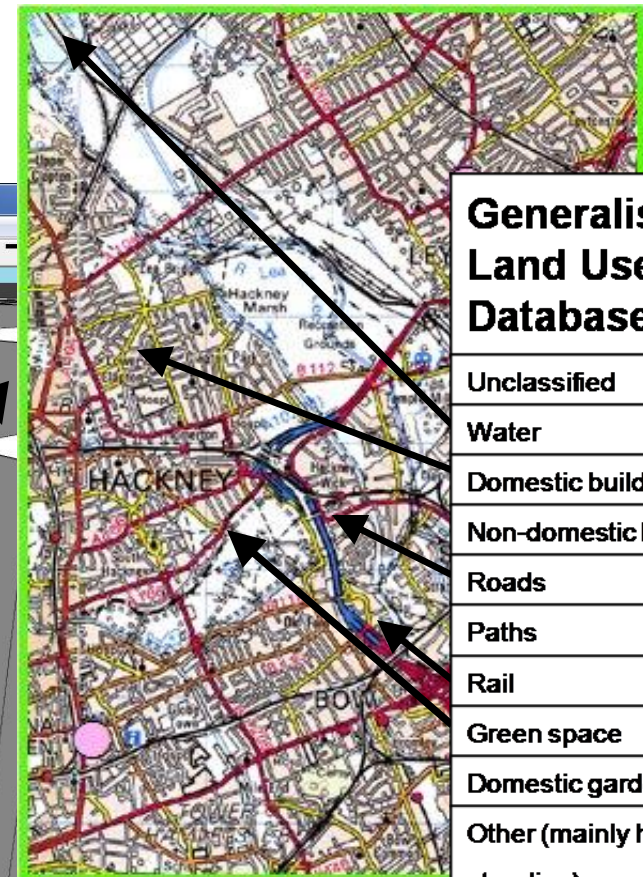
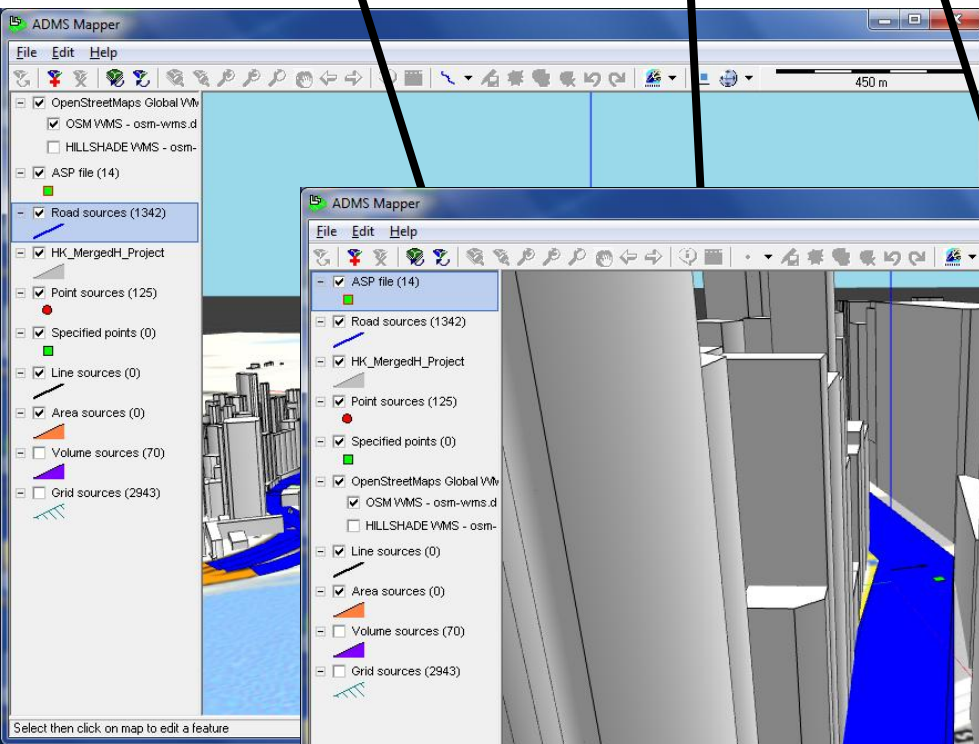
- How are the local variations derived?

Local  
changes in  
roughness

Local albedo  
and building  
geometry

Local  
availability  
of moisture

Thermal  
properties of  
the surfaces



## Generalised Land Use Database class

Unclassified

Water

Domestic buildings

Non-domestic buildings

Roads

Paths

Rail

Green space

Domestic gardens

Other (mainly hard  
standing)



# ADMS Temperature and Humidity Model: Parameterising urban datasets

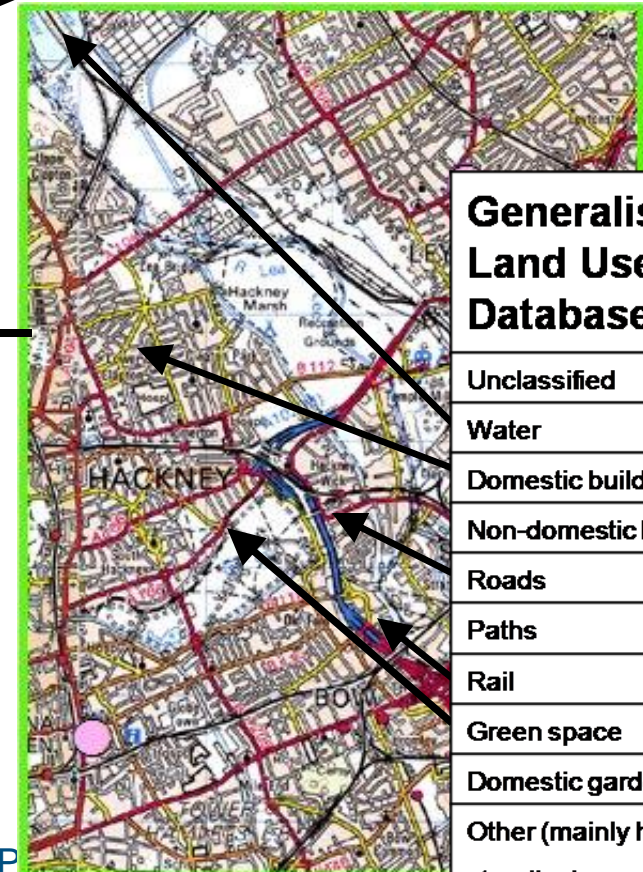
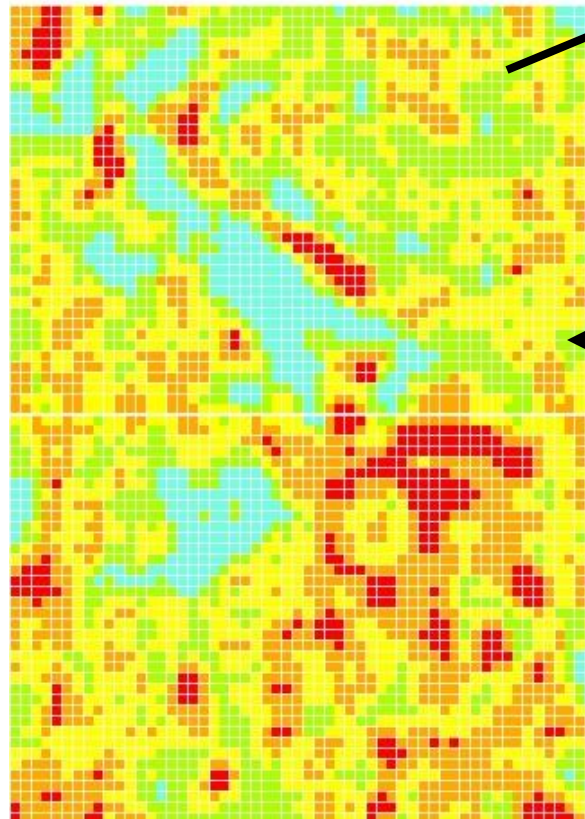
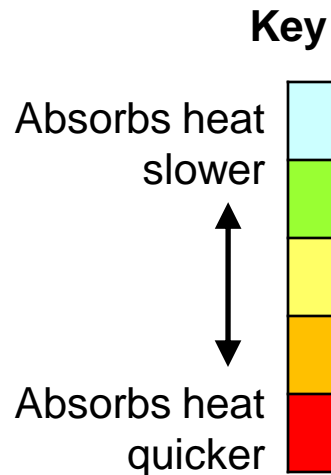
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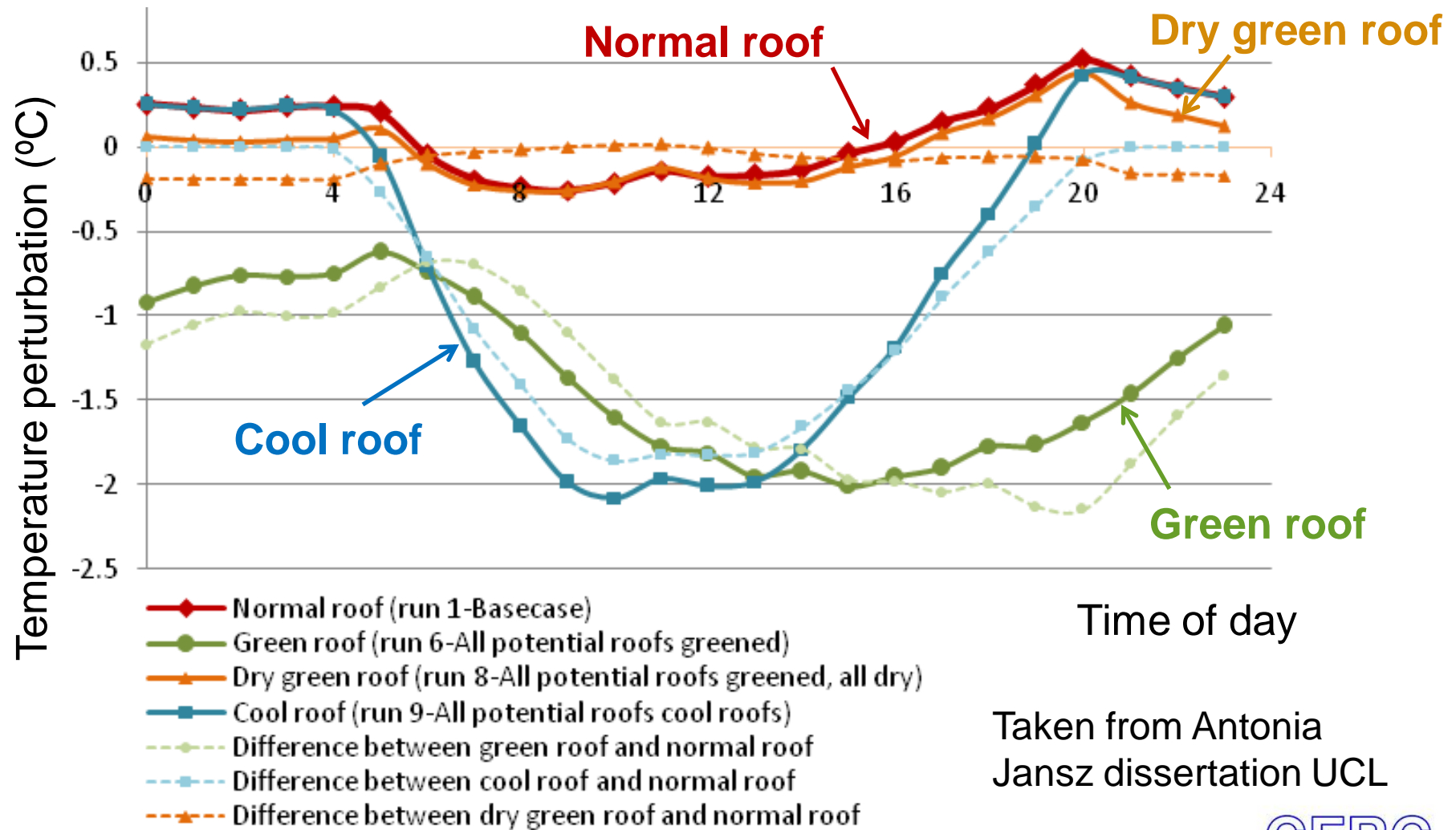
Domestic gardens

Other (mainly hard  
standing)

## Example case studies:

### Victoria Business Improvement District (UCL student dissertation)

#### Temperature perturbations/differences at roof top receptor

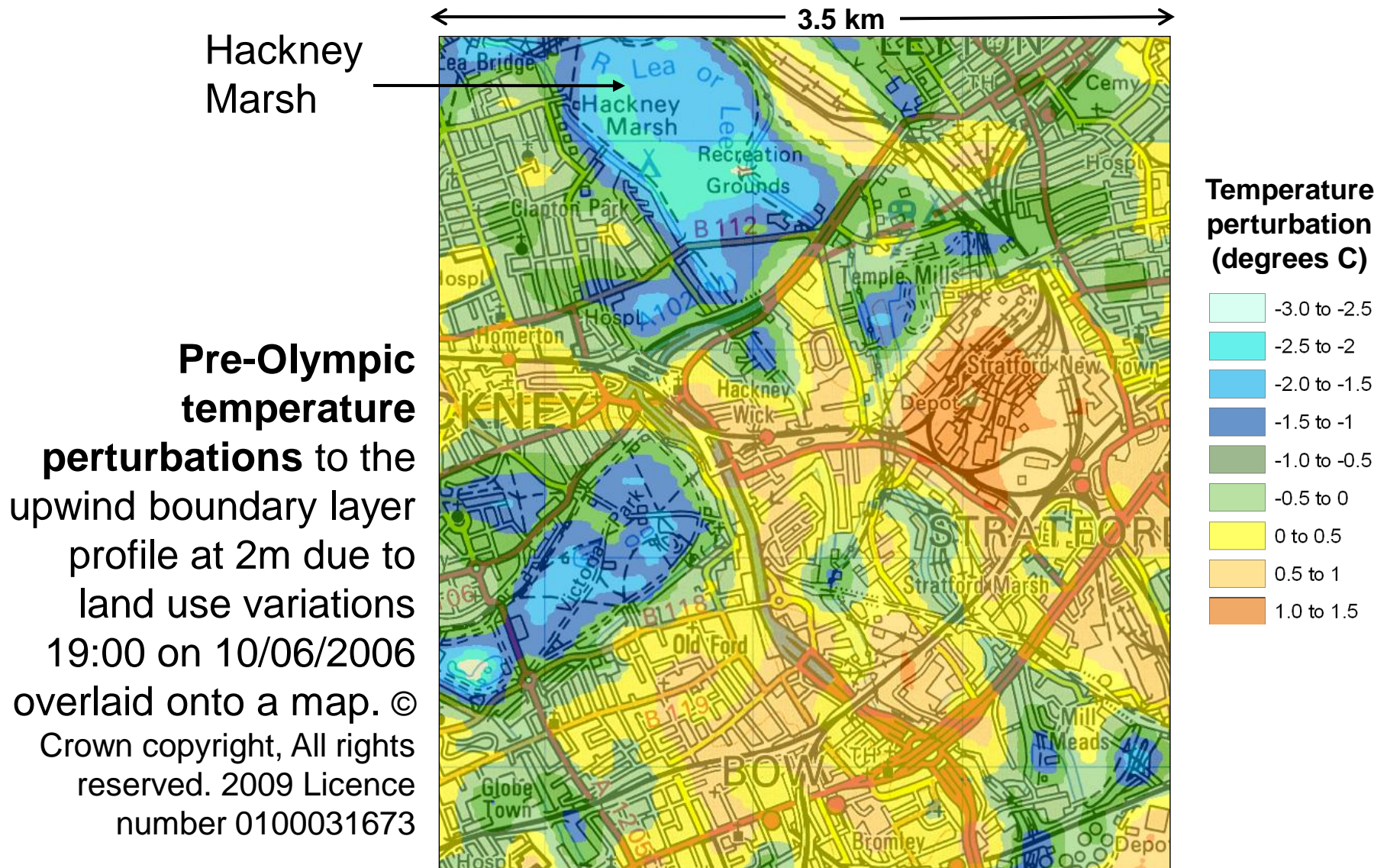


Taken from Antonia  
Jansz dissertation UCL



## Example case studies:

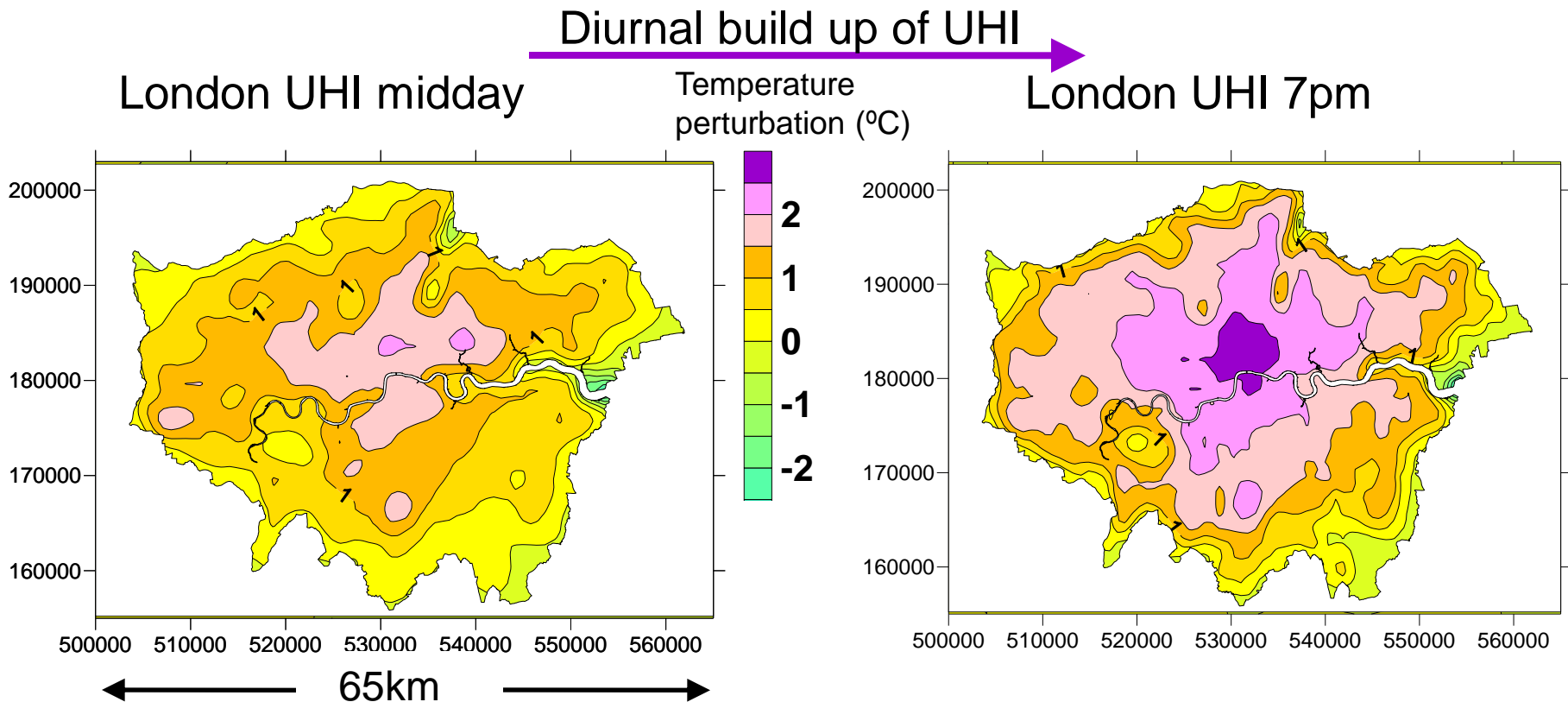
# Olympic Parkland development (LUCID project)



## Example case studies:

# London Urban Heat Island (ERASMUS Masters student)

- Preliminary modelling results encouraging
- Comparisons with the 1-km resolution UK Met Office mesoscale model (modified to account for UHI) reasonable
- Further validation against measurements in progress





# Summary

## ADMS-Urban

- Dispersion modelling system for urban areas, including advanced street canyon scheme, urban canopy model, complex terrain, link to regional models

## *air*TEXT

- Air quality forecasting service for London with over 15,000 subscribers that has ADMS-Urban at its heart

## ADMS Temperature and Humidity model

- Urban climate modelling system, for local urban planning assessments and city-scale 'urban heat island' analyses

Thank you for listening