Imperial College London

Spatial approaches to epidemiology and public health: experiences from SAHSU, UK

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The Small Area Health Statistics Unit (SAHSU)

- Commenced in 1987
  - following a recommendation of the Black Inquiry

"… encouragement should be given to an organisation … to co-ordinate centrally the monitoring of small area statistics around major installations producing discharges that might present a carcinogenic or mutagenic hazard to the public. In this way, early warning of any untoward health effect could be obtained."

London, HMSO, 1984

- London School of Hygiene and Tropical Medicine
- Imperial College London since 1996

SAHSU's terms of reference include:

- To develop and maintain databases of health data, environmental exposures as required to meet a specific need, and social confounding factors at the small-area level;
- To respond rapidly, with expert advice, to *ad hoc* queries from the funding departments about unusual clusters of disease, particularly in the neighbourhood of industrial installations;
- To develop the methodology for analysing and interpreting statistics relating to small areas

Examples of recent and current projects

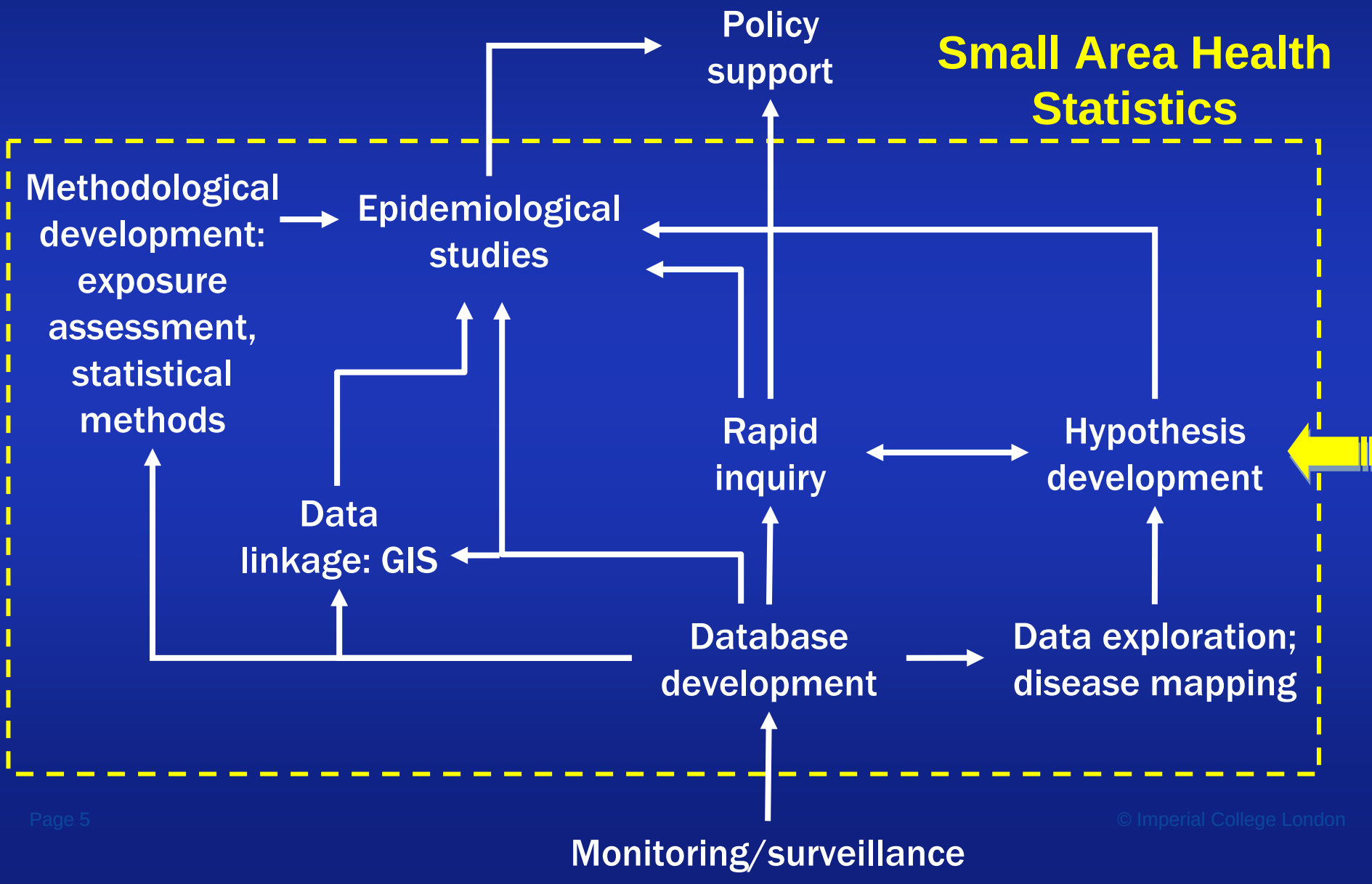
SAHSU projects:

- Chronic health effects of air pollution: SO_2 and black smoke
- Health effects of chlorination by-products in drinking water
- Multiple deprivation: environmental inequities and health implications
- Health effects in populations exposed to chemical industry emissions
- Health risks in populations living close to landfill sites

SAHSU-related projects

- Childhood cancer and leukaemias around mobile phone masts
- Adult cancers in populations living close to powerlines
- Air Pollution Modelling for Support to Policies on Health and Environmental Risks in Europe (APMoSPHERE)
- Health effects of air pollution episodes (part of Global Environmental Monitoring with Satellites study – GEMS)
- Integrated Assessment of Health Risks from Environmental Stressors in Europe (INTARESE)
- Health Effects and Risks of Transport Systems (HEARTS)
- Health and environment integrated methodology and toolbox for scenario assessment (HEIMTSA)
- The Rapid Inquiry Facility (RIF)

The role of SAHSU in policy support



Methods for research: GIS functionality

- Capture geographic data
- Integrate data into a common geographic form
- Provide a means for data validation & quality control
- Generate maps of disease, environmental hazards and socio-economic factors
- Enable modelling of unmeasured characteristics
- Allow linkage or integration of models
- Provide a basis for exposure assessment

Determinants of exposure

- Hazard intensity
  - Spatial distribution
  - Temporal variability
  - Micro-environment
- Population distribution
  - Population pattern
  - Time-activity
- Behaviour
  - Consumption
  - Activity level
  - Lifestyle
- Physiography
  - Stature
  - Age
  - Gender

Exposure occurs as people move through, and reside within, a changing hazard field

How can we assess exposures?

- Direct methods
  - Bio-monitoring
  - Personal exposure
  - Self-reporting
- Indirect methods
  - Natural recorders
  - Exposure proxies
  - Spatial modelling
  - Process modelling

Typically environmental exposure assessment is based on the use of routine monitoring sites

Sources of data for exposure modelling

- Environmental surveys
  - Soils, geology etc
- Ground-based monitoring
  - Routine monitoring networks
  - Purpose-designed surveys
  - Natural monitors
- Earth observation
  - Satellites
  - Airborne monitors
- Census data
  - Population censuses

Exposure modelling

- Monitoring station
- Indicators
- Source-receptor modelling
  - Models exposures by simulating relationships between source and receptor
- Interpolation
  - Models spatial patterns of exposure on the basis of monitored (georeferenced) data (with or without covariates)

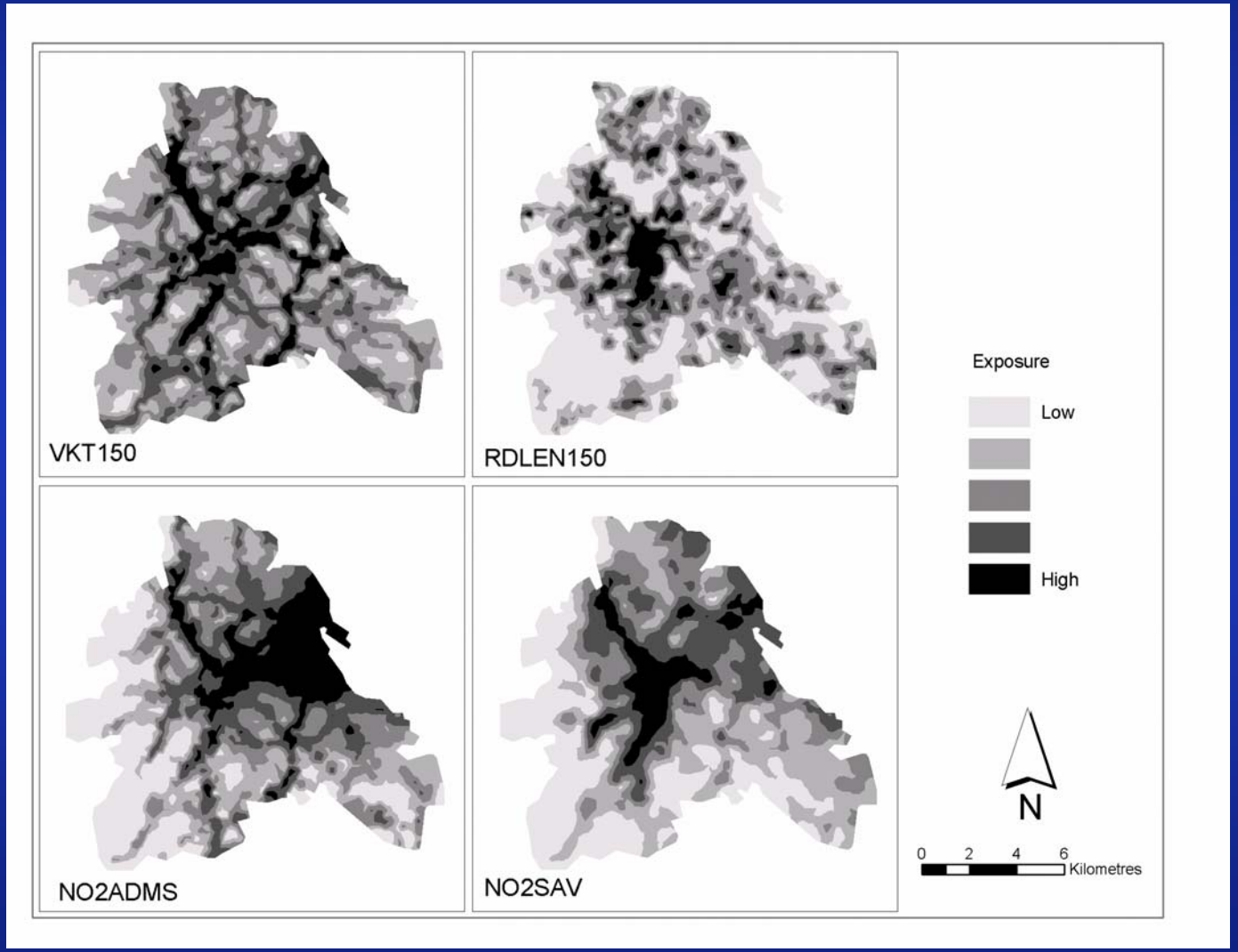
Example: exposure to air pollution

- Air pollution has been a policy concern in Europe since the late 1970s
- Historically, episodes associated with fossil fuel combustion provided evidence of adverse health effects
  - London 1952 and 1962
- Today, the focus is on traffic-related air pollutants (e.g. PM_{10} and NO_x)
- WHO global burden of disease estimated 800,000 premature deaths worldwide in 2000
  - Western Europe: 12,000 (men) and 11,000 (women)

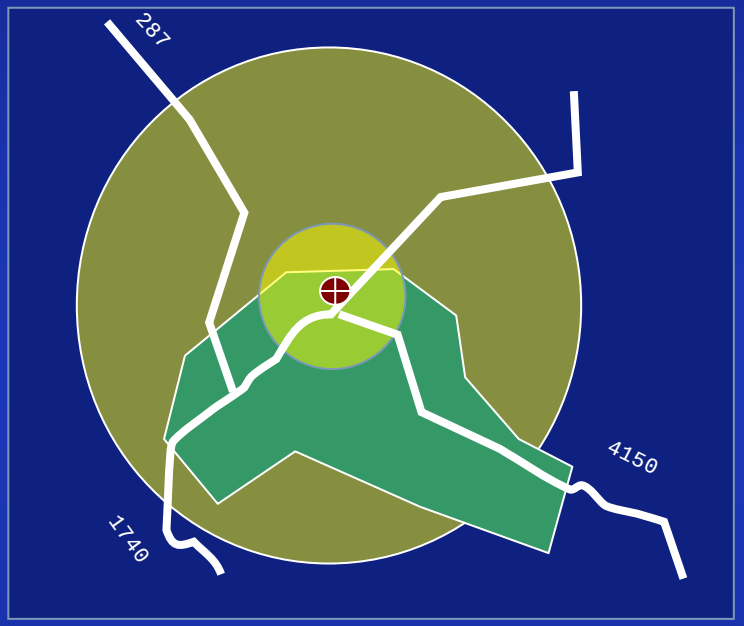
Indicators of traffic-related air pollution

- Distance to nearest (main) road
- Road density within X (e.g. 150) metres
- Traffic volume on nearest (main) road
- Traffic volume on nearest main road/distance
- Traffic volume in neighbourhood (e.g. census tract)
- Vehicle kilometres travelled on all roads within radius of X (e.g. 150) metres
- Emissions from road traffic within X (e.g. 150) metres
- Modelled concentrations of marker pollutant (e.g. NO2)

Comparison of exposure maps: traffic-related air pollution, Sheffield



Land use regression



1. Buffer around each monitoring site at pre-defined distances
2. Extract measures of predictors (e.g. traffic volume, land cover) for each buffer zone
3. Use multiple regression to develop predictive model

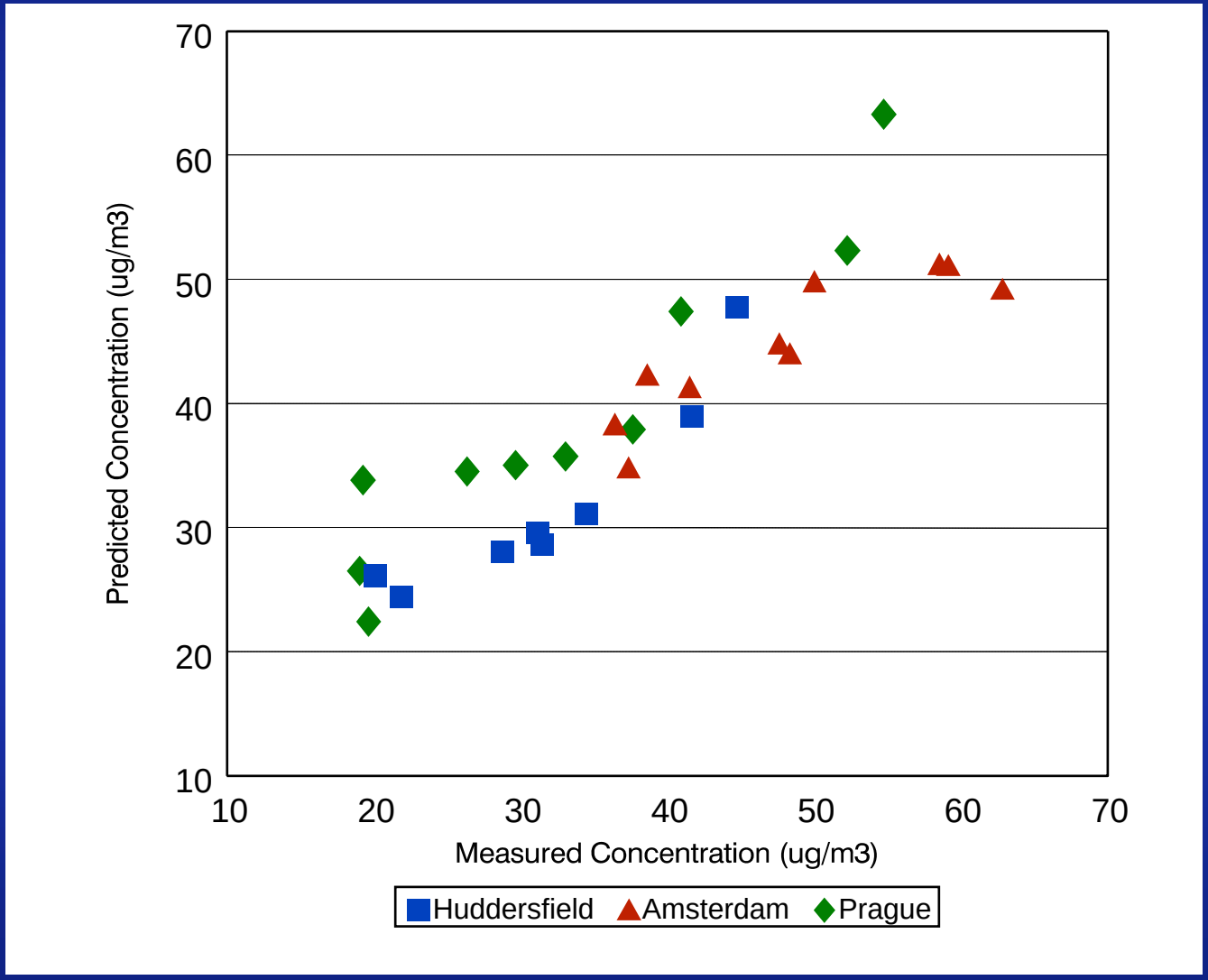
$$C = 38.5 + .003705*Traff + 0.232*Land – 5.673*\log_{10}Alt$$

where:

$$Traff = 18*Tvol_{0\text{-}40} + Tvol_{40\text{-}300}$$

$$Land = 8*HDH_{0\text{-}300} + Ind_{0\text{-}300}$$

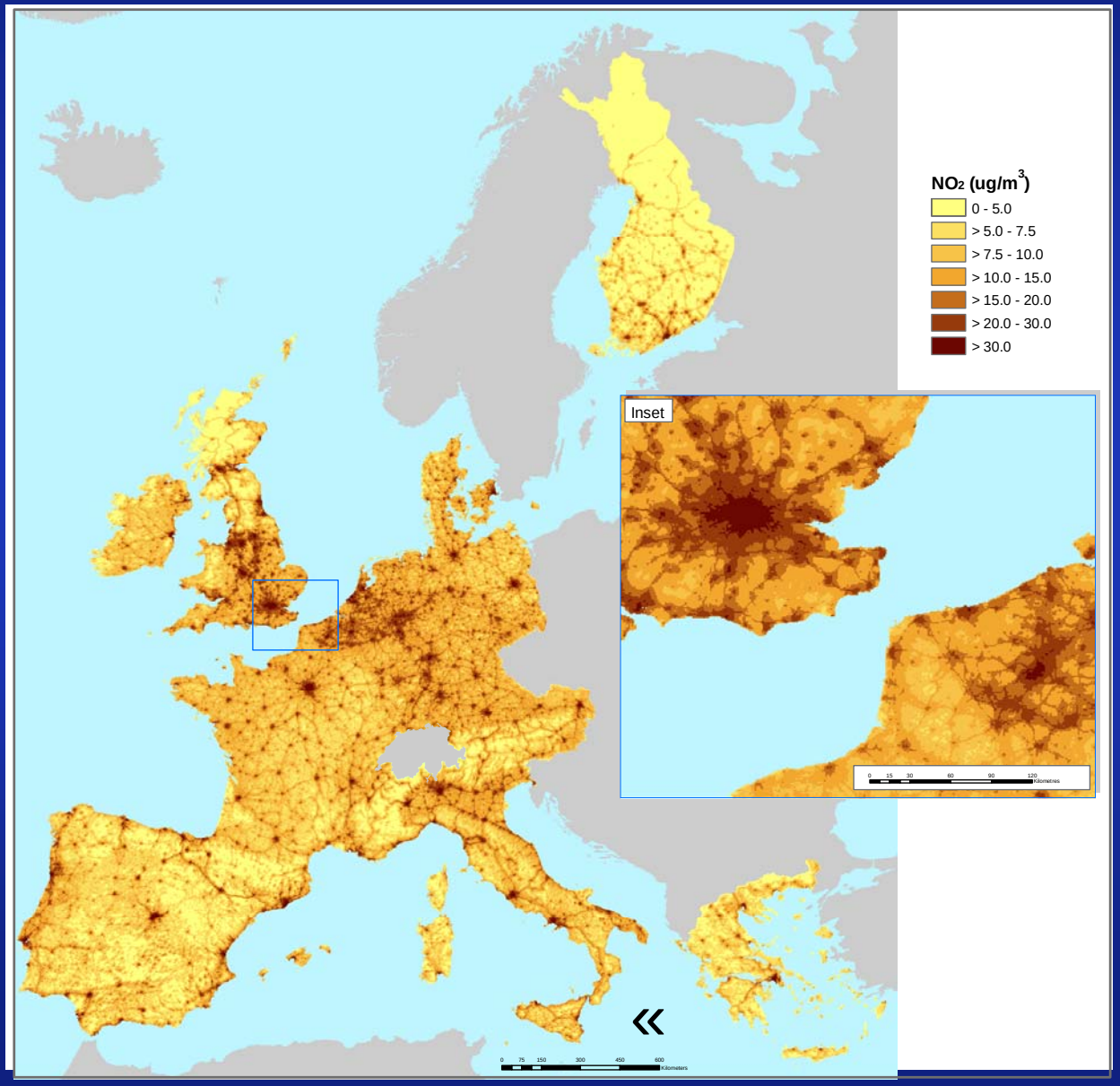
The SAVIAH study: model validation



Performance of four exposure models: Huddersfield

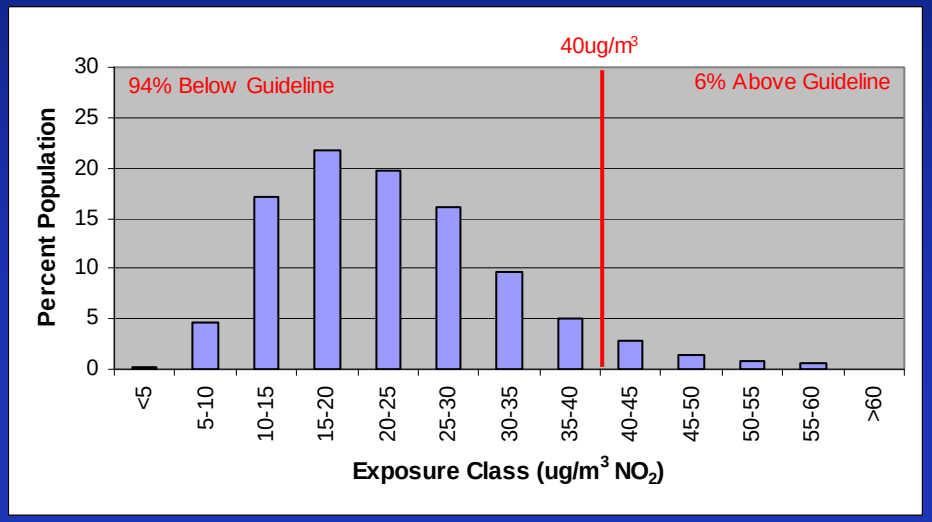
Method	r^2 (n=8)	SEE (ug/m^3)	Mean exposure (ug/m^3)	% exceedance (NAQS)
Kriging	0.44	6.45	31.6	8.0
Dispersion modelling	0.63	5.25	27.1	4.3
Moving window	0.67	4.92	26.9	2.9
Regression	0.82	3.68	30.0	7.5

NO2 EU-wide

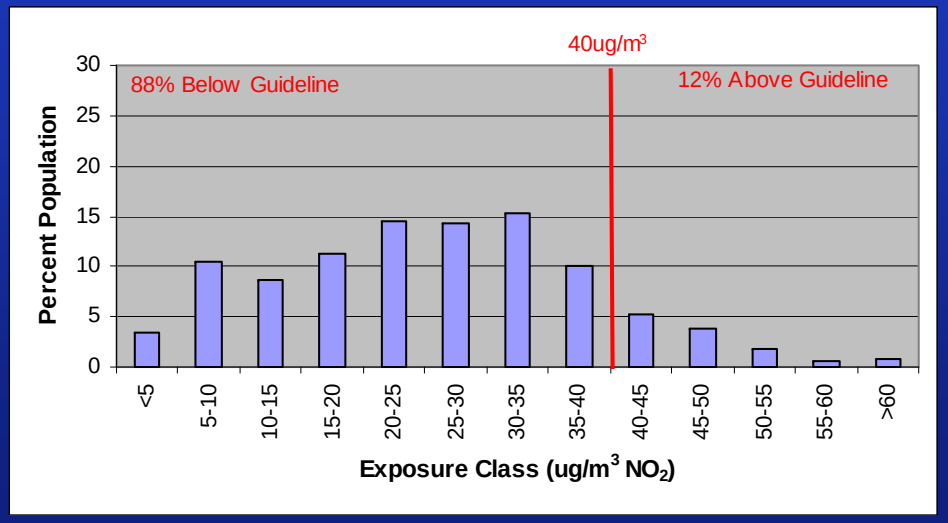


Modelled 2001 annual mean background NO2 Concentrations

Exposure: EU level

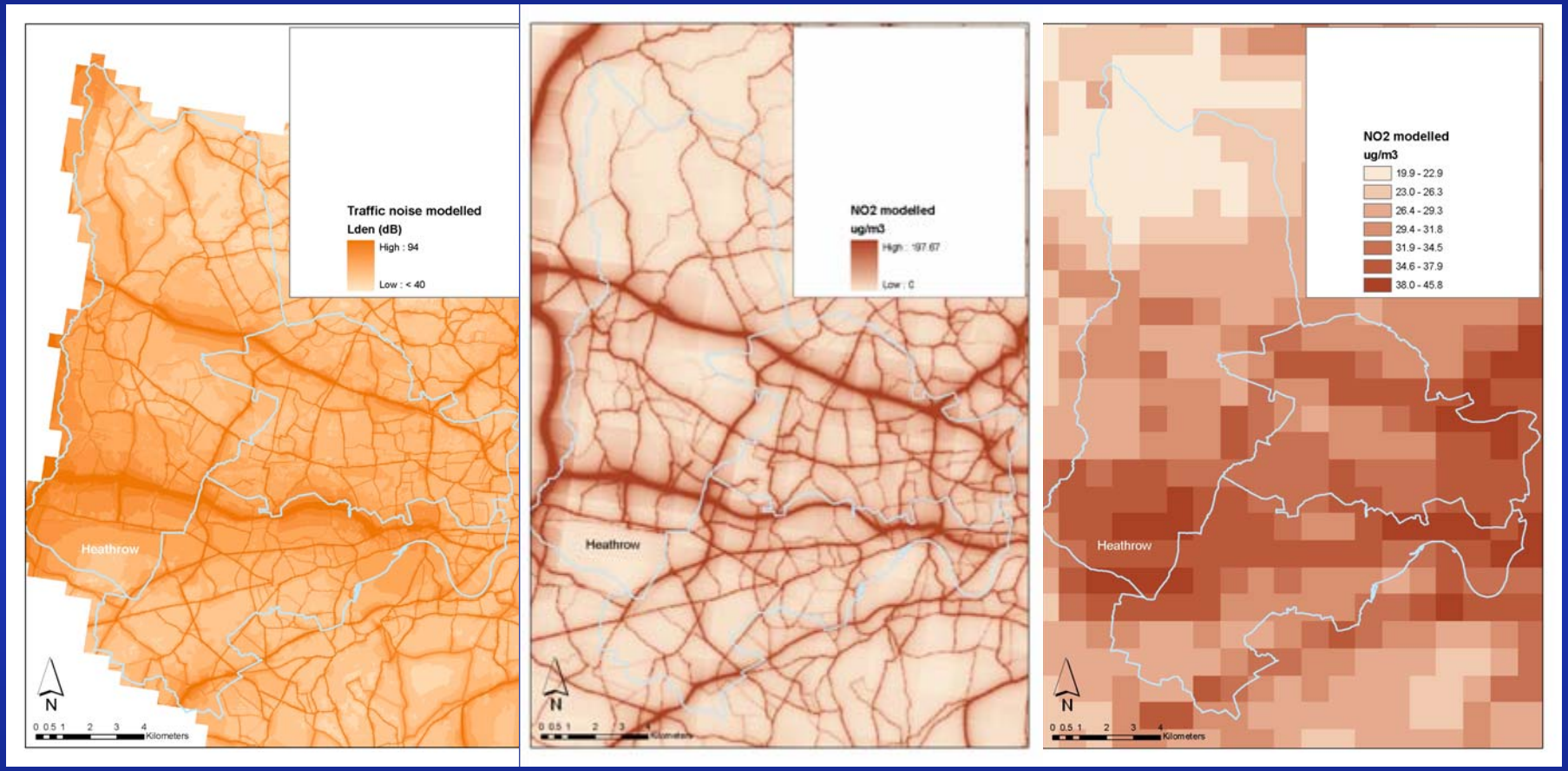


NO_2 – Modelled



NO_2 – Nearest Monitor

Air and noise pollution

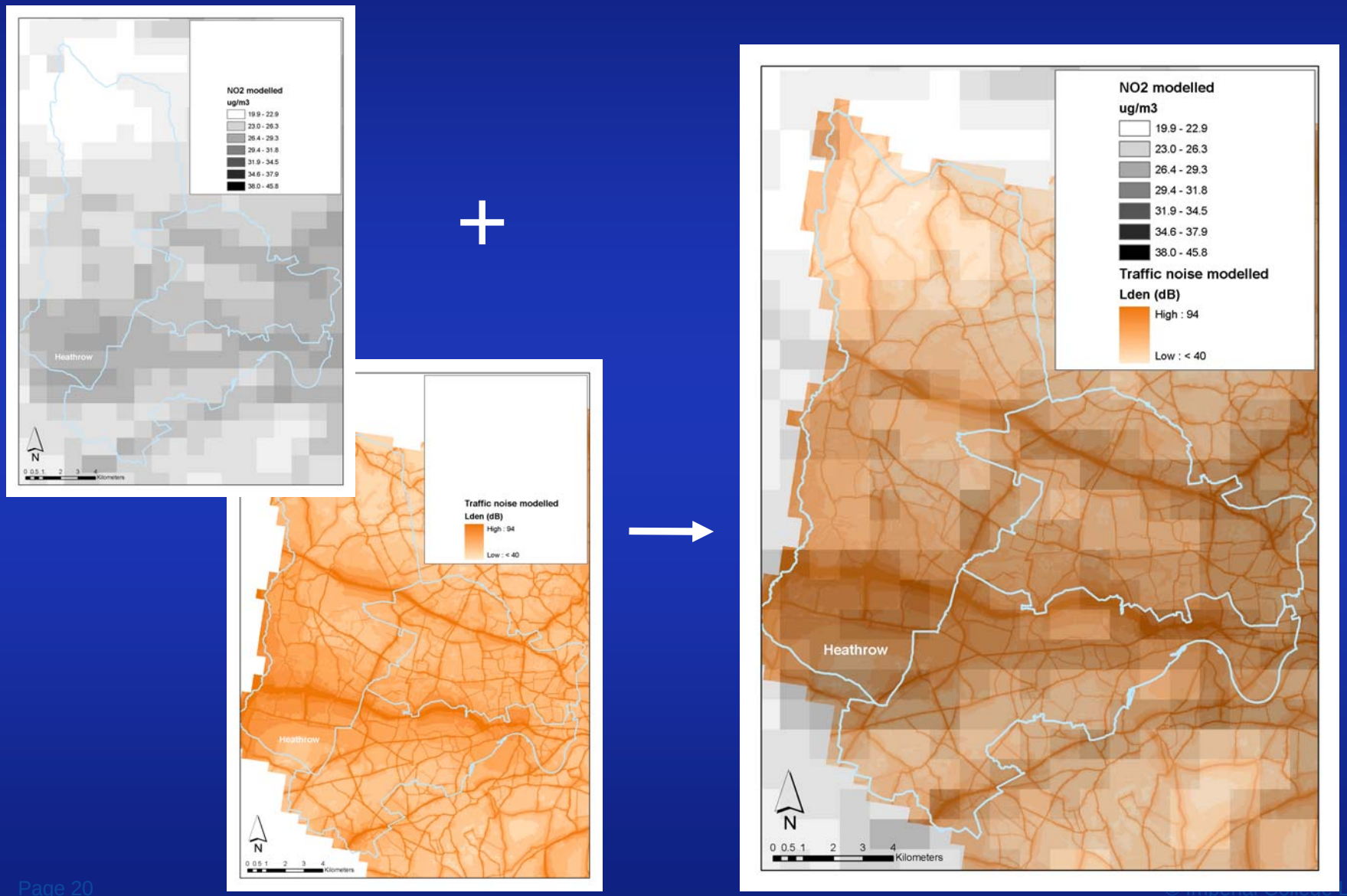


Road traffic Noise Lden

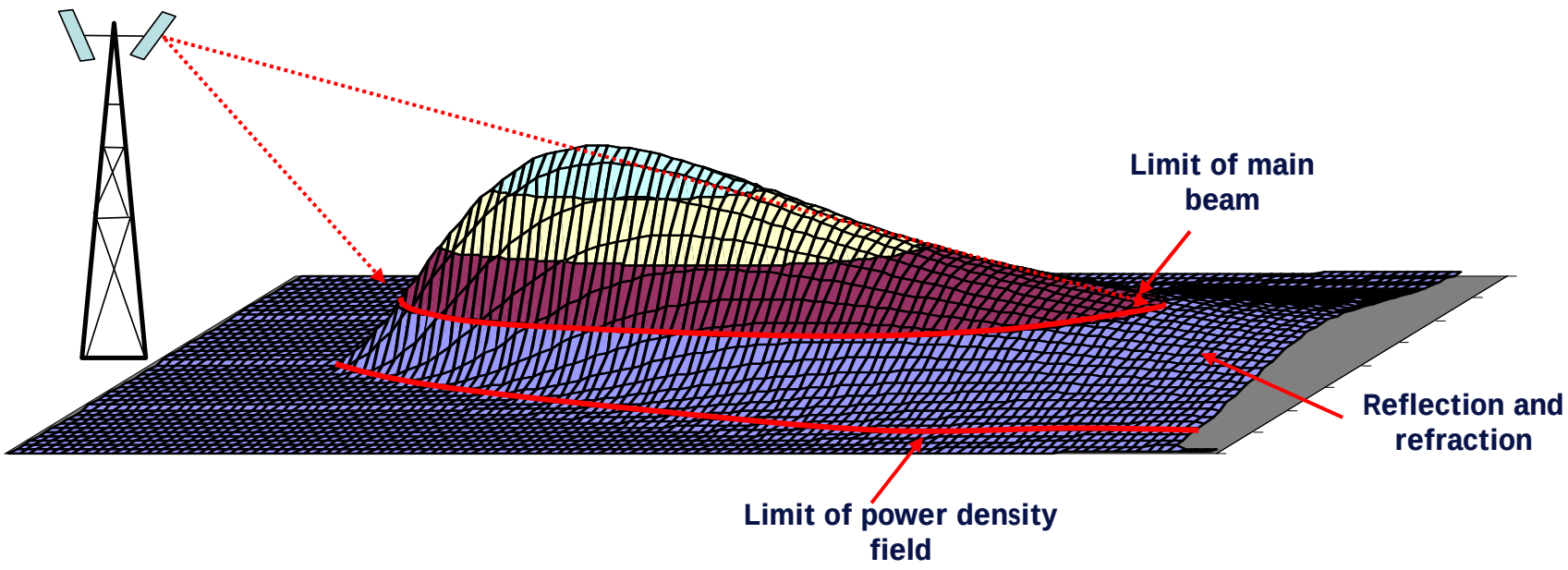
NO2 modelled ADMS-Urban

NO2 modelled APMoSPHERE

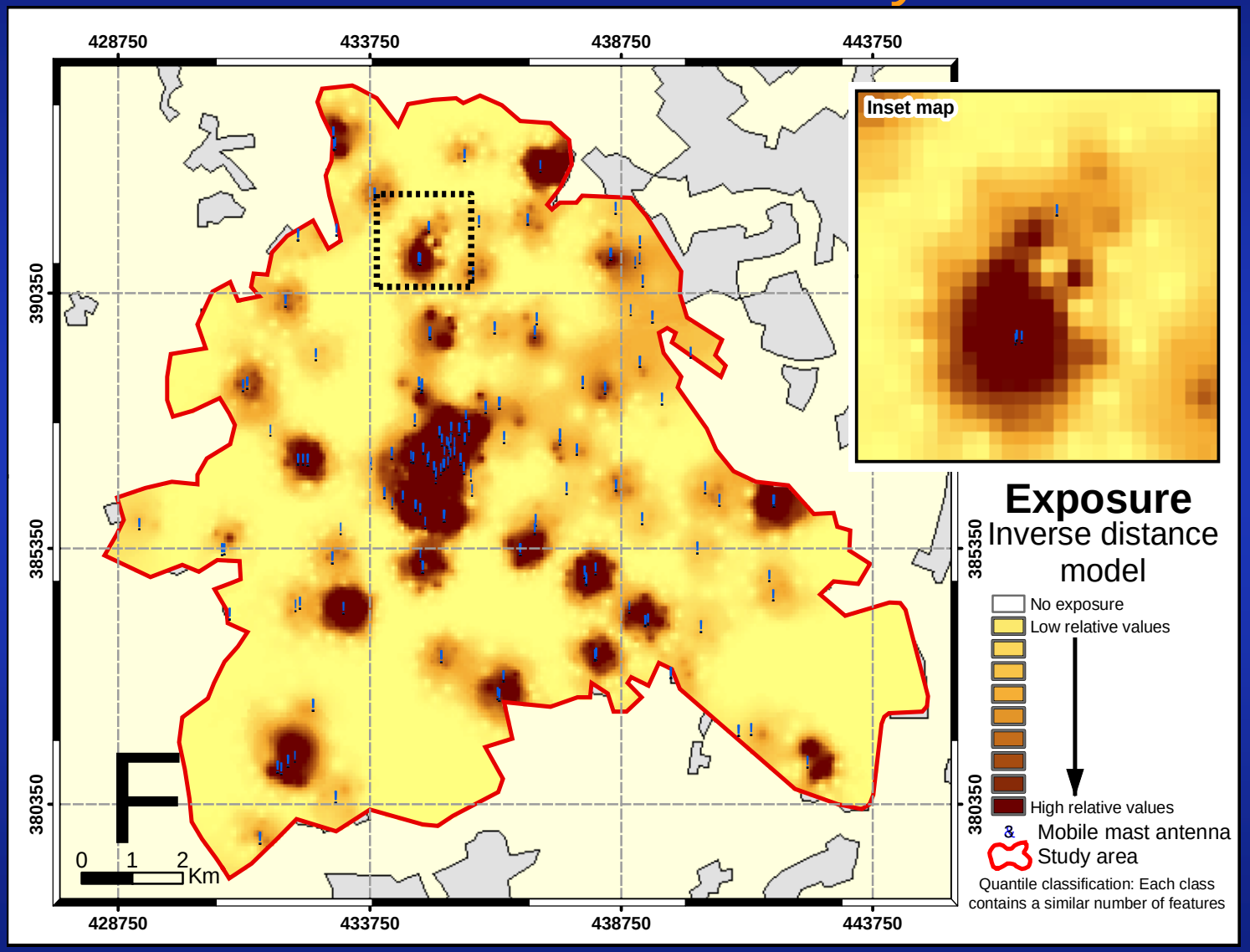
Noise and air pollution – Heathrow, UK



EMF exposures around a mobile phone mast



Modelled EMF: Mobile masts study

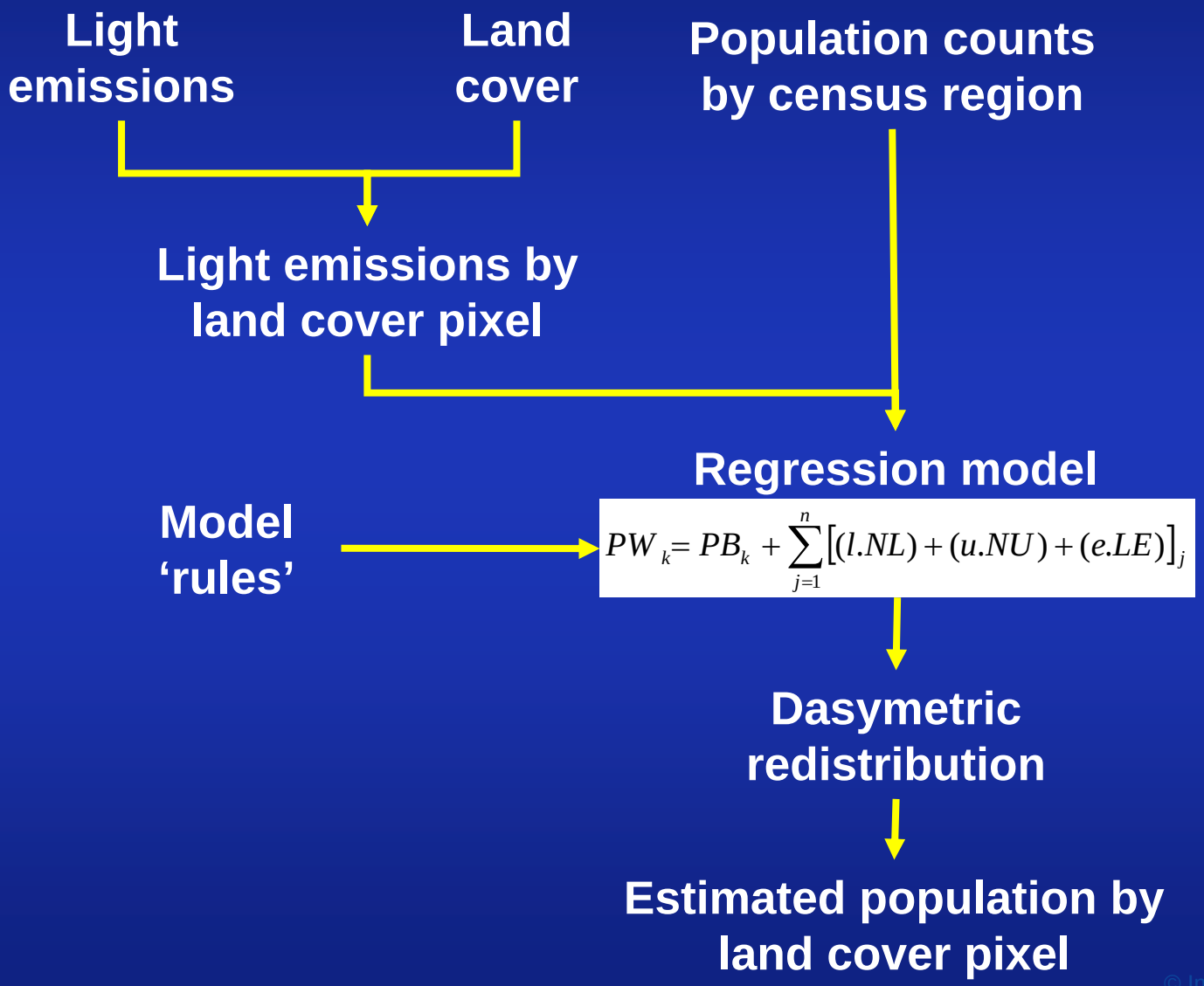


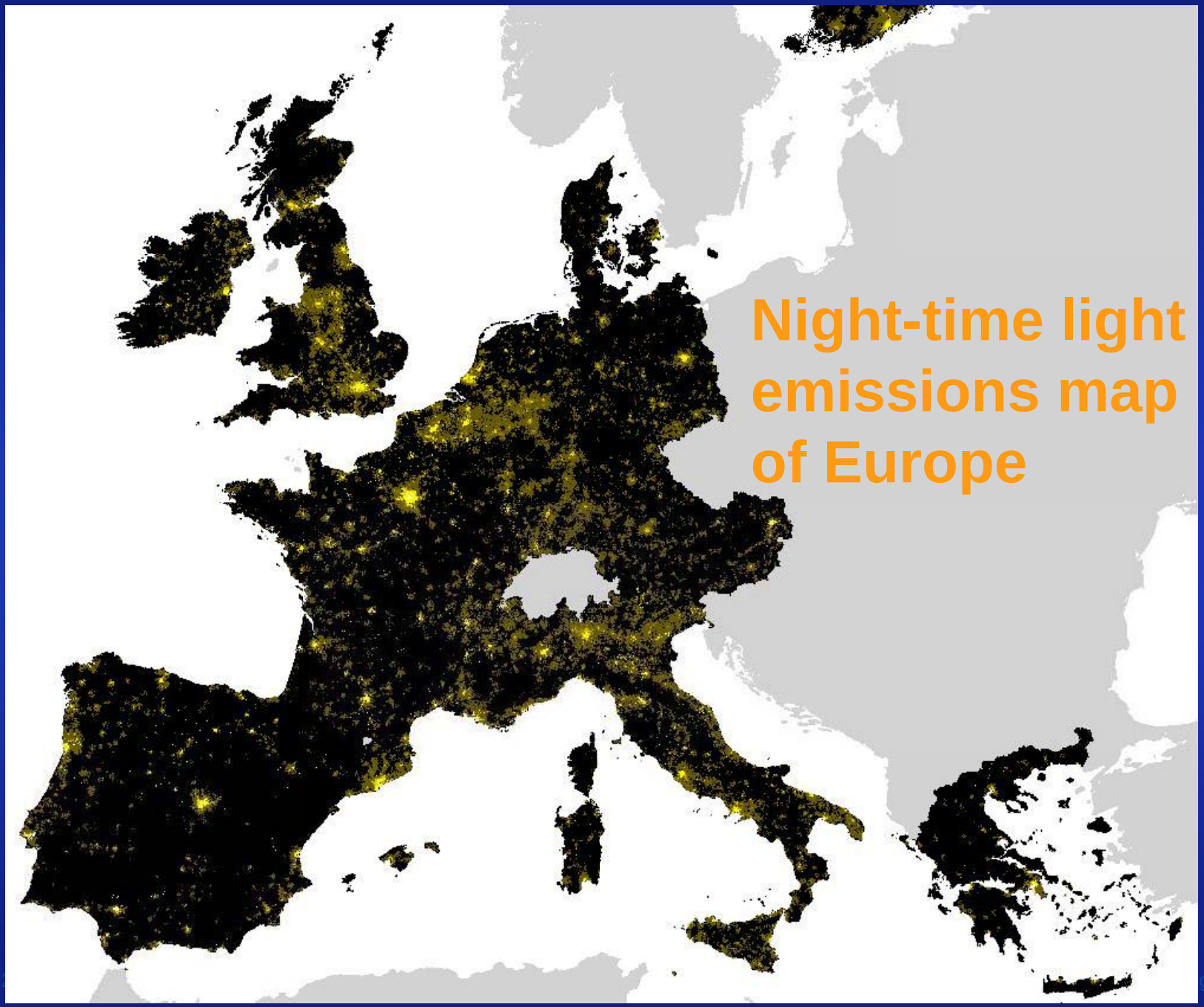
Population data

- Reliable population data are essential both as a basis for exposure assessment and risk assessment.
- Census data are often available at a relatively detailed level of disaggregation (e.g. ward, census tract), but in many countries census tracts are large, population data are not released, and censuses are unreliable.
- Data are also often needed for geographical zones that do not correspond to administrative boundaries
- Populations change over time – including between censuses

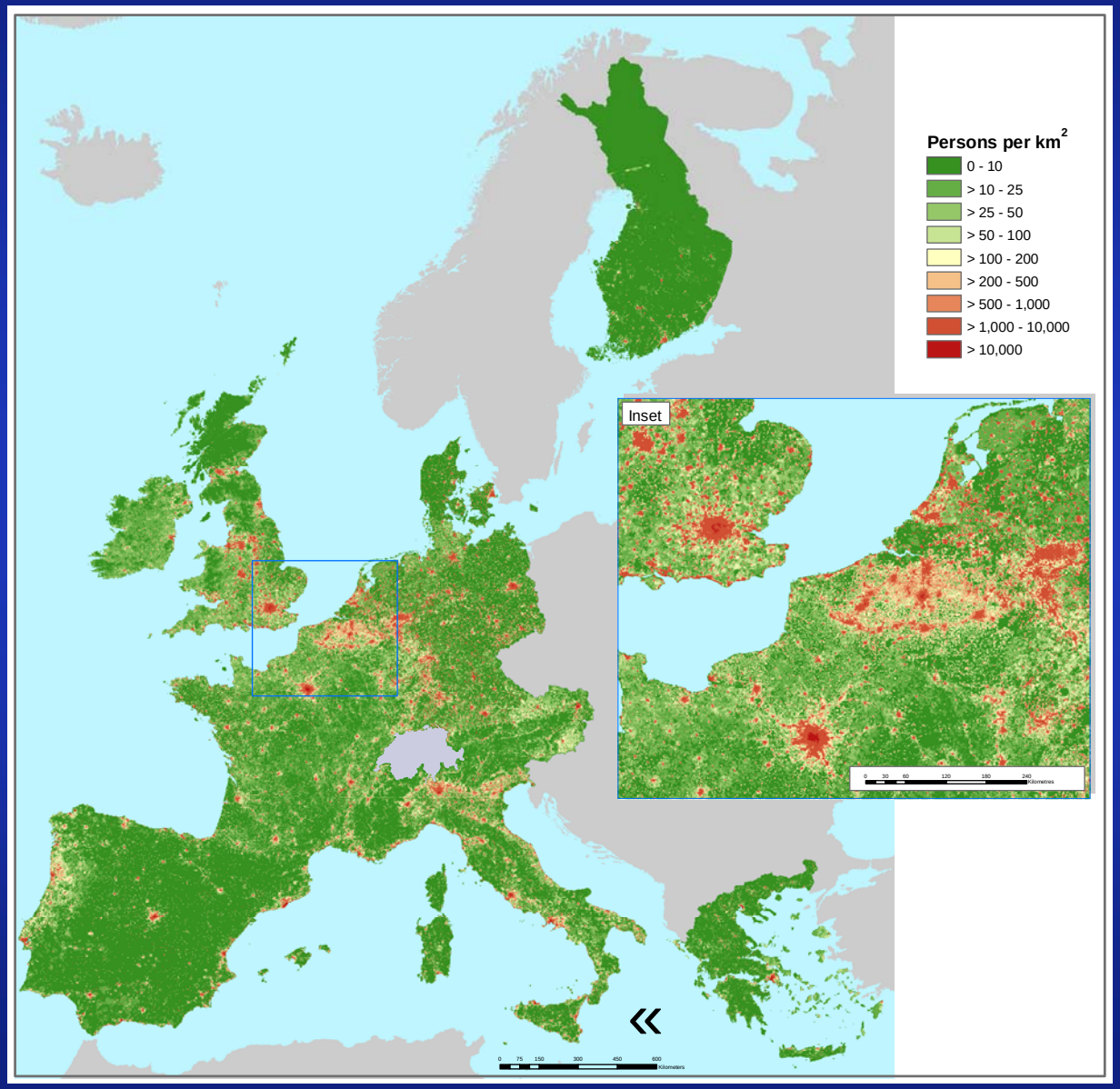
Errors/variations in small-area population counts can create major uncertainties, especially where health events are rare

Dasymetric Mapping Method




Night-time light emissions map of Europe

EU-wide population density map

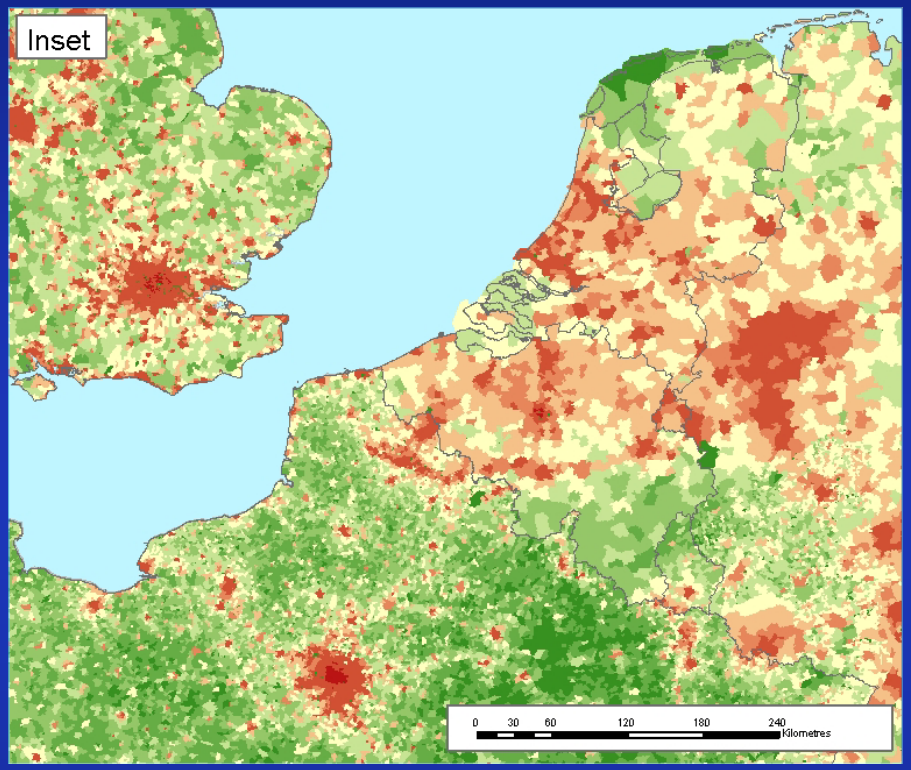


Validated in GB using postcode data for 1991 and 2001.

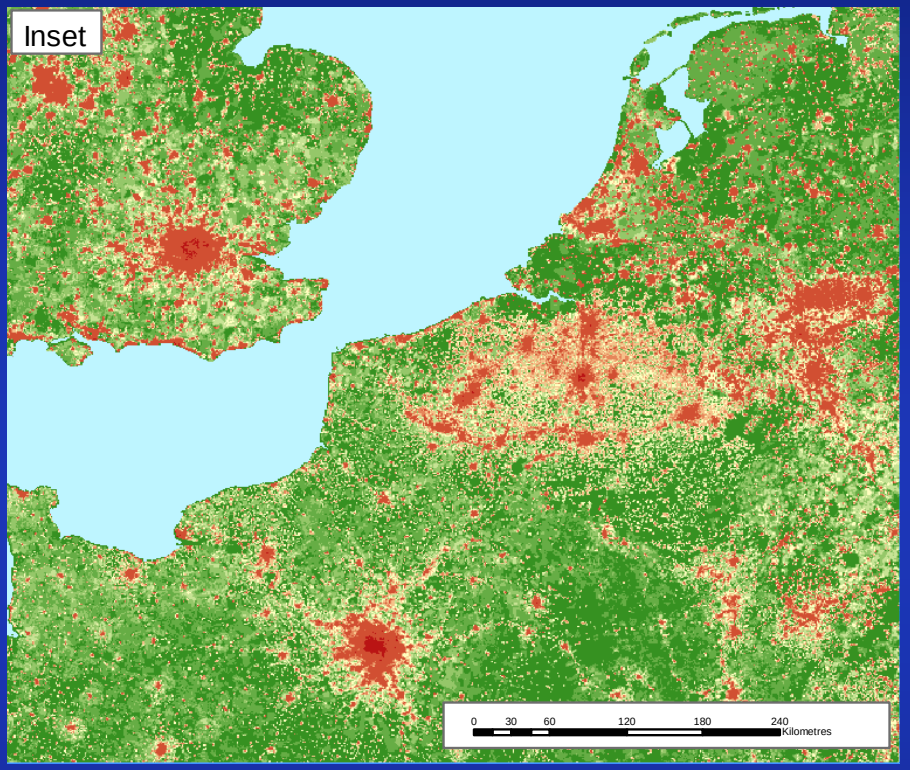
GB Strategy 1:
R^2 = 0.92 (1991)
R^2 = 0.90 (2001)

EU Strategy 1:
R^2 = 0.88 (1991)
R^2 = 0.87 (2001)

Population density



NUTS 5



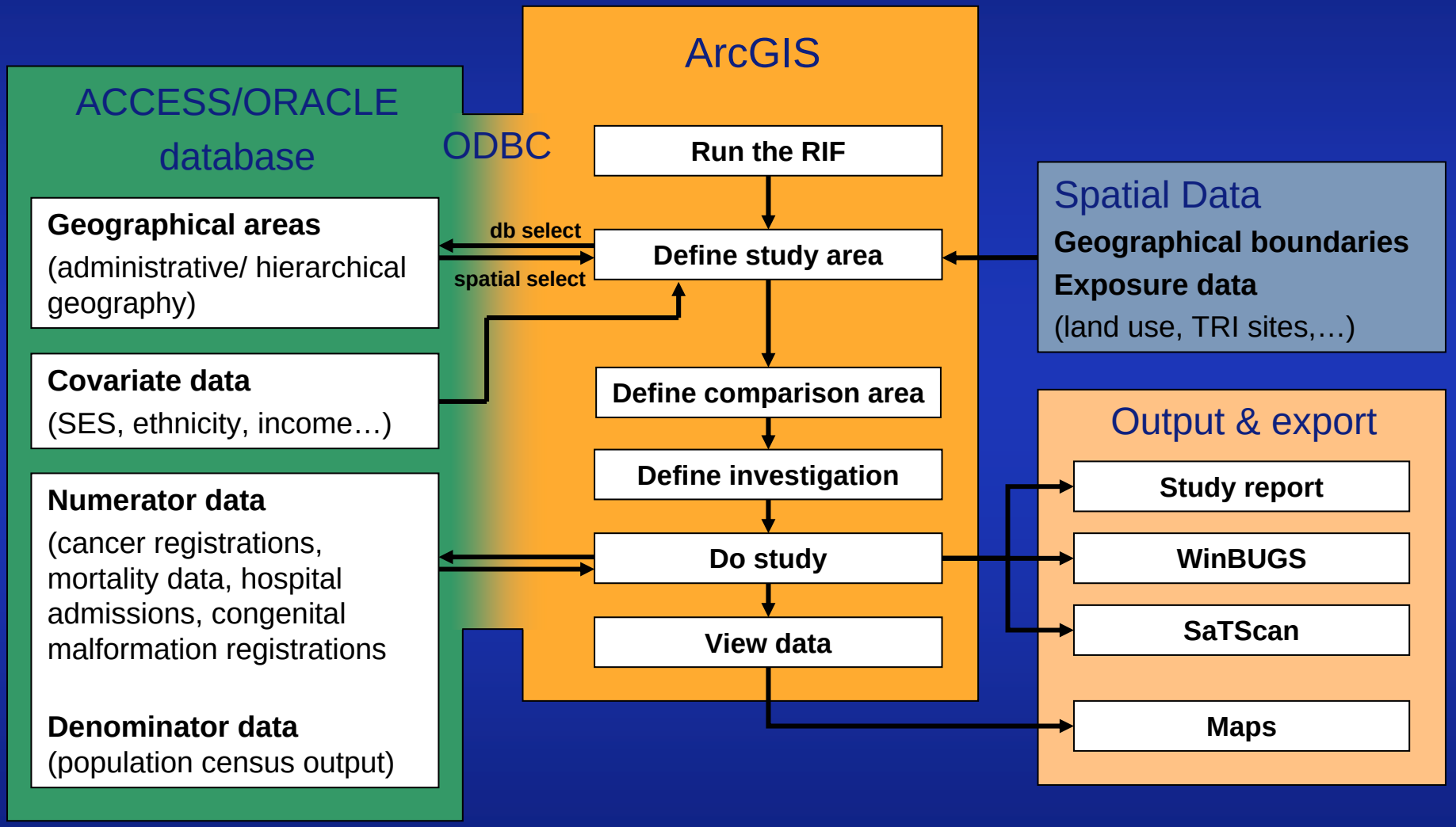
1km

Linking environmental exposures, health outcomes and risk

- The RIF is a tool that allows users to assess relationships between the environment and health
  - Embedded in ESRI® ArcGIS
  - Links spatial and non-spatial data
  - Risk analysis around putative hazardous sources
  - Disease mapping

- It aims to provide improved understanding of the links between environmental exposures, health outcomes and risk

Outline of RIF

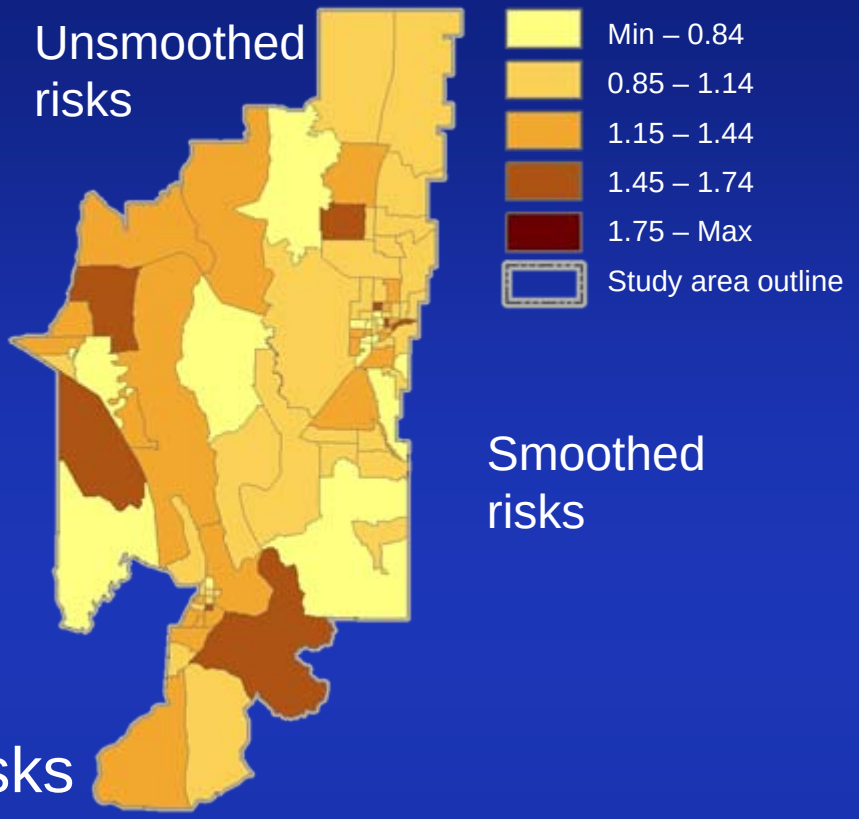


RIF analysis

- Risk exposure analysis allows assessment as to whether a risk factor has a statistical association with a health outcome in a local population, producing:
  - directly standardised rates and indirectly standardised rate ratios
  - in user defined distance bands around one or more user defined point or area sources

- The disease mapping functionality of the RIF allows a user to visualise mortality or morbidity rates and spatial patterns of health outcomes.
  - maps of directly and indirectly standardised rate ratios
  - smoothing of indirectly standardised rate ratios via empirical Bayesian estimation.

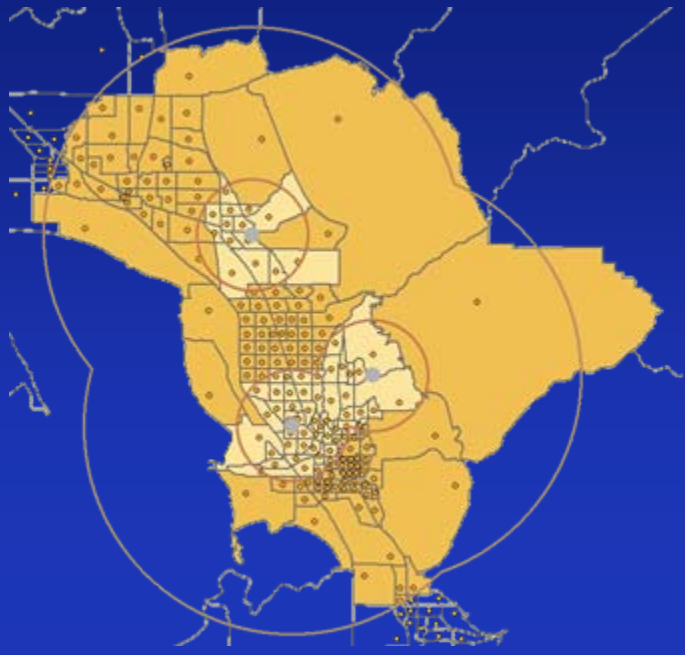
Disease Mapping



- Small areas/rare diseases…
  risks become unstable
  If E=0.2,
  risk = 0 if 0 cases observed
  risk = 5 if 1 case observed
- Smoothing methods shrink risks towards the global or local average risk
- The higher the uncertainty associated with the risk, the higher its shrinkage

Risk analysis

- Select on screen or import a shapefile
  - Select points or areas
  - defined distance bands
  - Input output from dispersion models
  - Classify by shapefile attributes



- Select by geographical area e.g. census block group
  - Classify by a covariate

Data issues

- Data completeness
- Data ascertainment levels
- Measurement errors, reporting errors, detection limits
- Changes in data collection over time
- Timeliness of data
- Appropriateness of data
- Error propagation (errors multiply within studies)

Exposure and population data issues

- Exposure data :
  - Derived from common methods and datasets across large areas to support large cohort studies
  - Consistent and high-resolution to support epidemiological research and facilitate comparison across e.g. the EU, USA etc
- Population data
  - Adequacy of population data will be dependant on:
    - Errors, Specificity (who are the targets?), Timeliness
  - Scale and generalisation
    - Individual versus area, small number problems
  - Population mobility
    - Is place of residence an adequate basis for exposure modelling and health mapping? Past exposures and past locations (latency)

Conclusions

- Data availability and quality are crucial limitations
- Designing valid spatial epidemiological and public health studies needs care
- Spatial representation is usually the decision of the analyst, not an inherent characteristic of the feature
- Computing does not equal accuracy
- Errors can occur at any stage in a project and may relate to different factors
- The way data is mapped can mask, amplify or compound errors arising from data use/mis-use
  - “a good map of bad data looks better than a bad map of good data”
  - We need good data and valid methods to produce good maps

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www.imperial.ac.uk

www.sahsu.org

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Literature

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- Jarup L; Best N; Toledano MB; Wakefield J; Elliott P. (2002) Geographical epidemiology of prostate cancer in Great Britain. Int J Cancer. 97: 695-699
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Extra slides

The GEMS Project

1. Background
   - EU funded project; started March 2005; ends March 2009
   - Aim is to test and evaluate the use of Earth Observation data for environmental and health applications
2. Methods
   - Case-crossover design to examine associations between air pollution/temperature and mortality during major episodes (2003) compared with synoptically matched control periods in 2002
   - Air pollution initially being modelled on basis of local dispersion models + long-range models (informed by weather data from satellites)
   - Later analysis to attempt to use direct observations of air pollution from satellites
   - Future work aimed at exploring capability to predict health impacts of impending air pollution episodes (as early warning for public and health services) – e.g. 3-5 days in advance
3. Issues/problems
   - Poor resolution of satellite data both horizontally and vertically (integration through deep column of atmosphere)
   - Interactions between local and long-range components of PM mix, and with temperature?
   - Complex patterns of health effects during long episodes due to harvesting, adaptation (e.g. medication use, change in behaviour patterns)

GEMS UK health study