



**D/EP/Lazio**

Dipartimento di Epidemiologia del Servizio Sanitario Regionale  
Regione Lazio

# **APPLICAZIONE DELLE STIME MODELLISTICHE DEGLI INQUINANTI AGLI STUDI EPIDEMIOLOGICI**

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*Dipartimento di Epidemiologia,  
Servizio Sanitario Regionale, Lazio*

# Gli effetti sulla salute dell'inquinamento possono essere

## Acuti

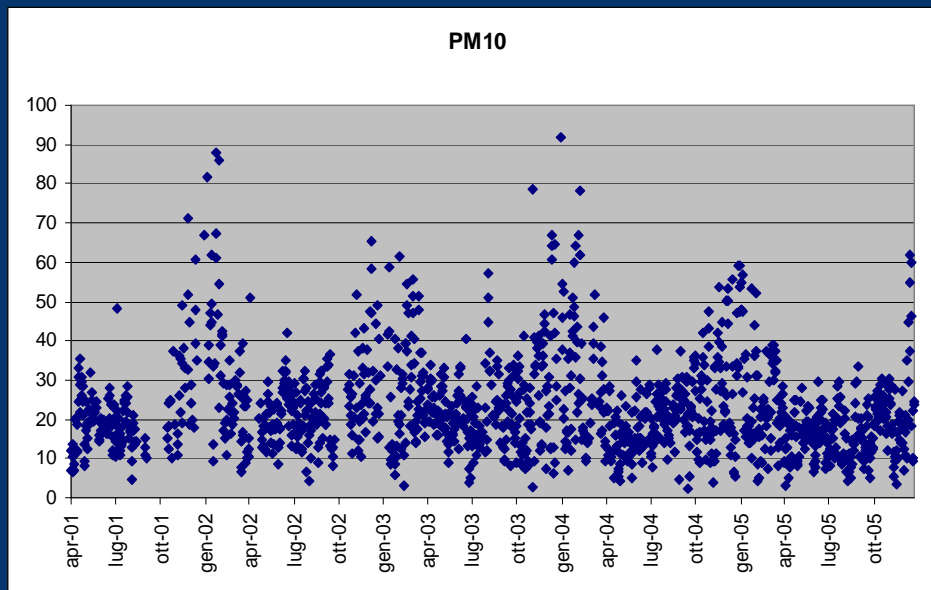
- ✓ legati a rapide variazioni dell'esposizione:  
(incrementi della concentrazione giornaliera degli inquinanti),
- ✓ con latenza breve (0 – 5 giorni dall'esposizione)

Studi di serie temporali o case crossover

## Cronici

- associati ad esposizioni prolungate nel tempo  
(medie annuali dell'inquinante)
- che si manifestano a lunga distanza dall'esposizione  
(da 1 a 10+ anni)

Studi di follow-up



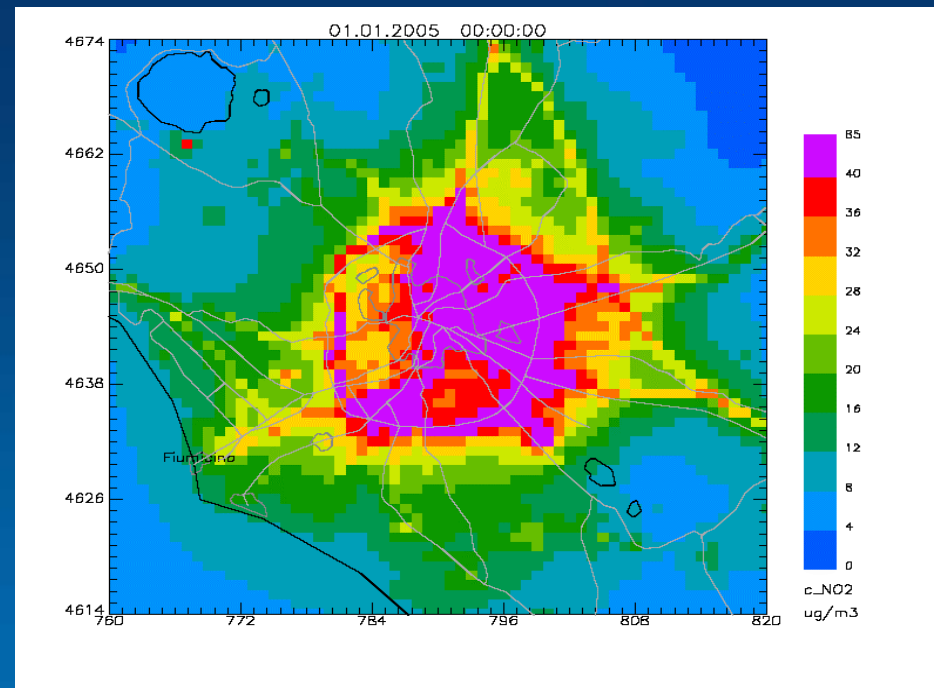
Effetti Acuti:

Differenze temporali

Effetti cronici:

Differenze spaziali

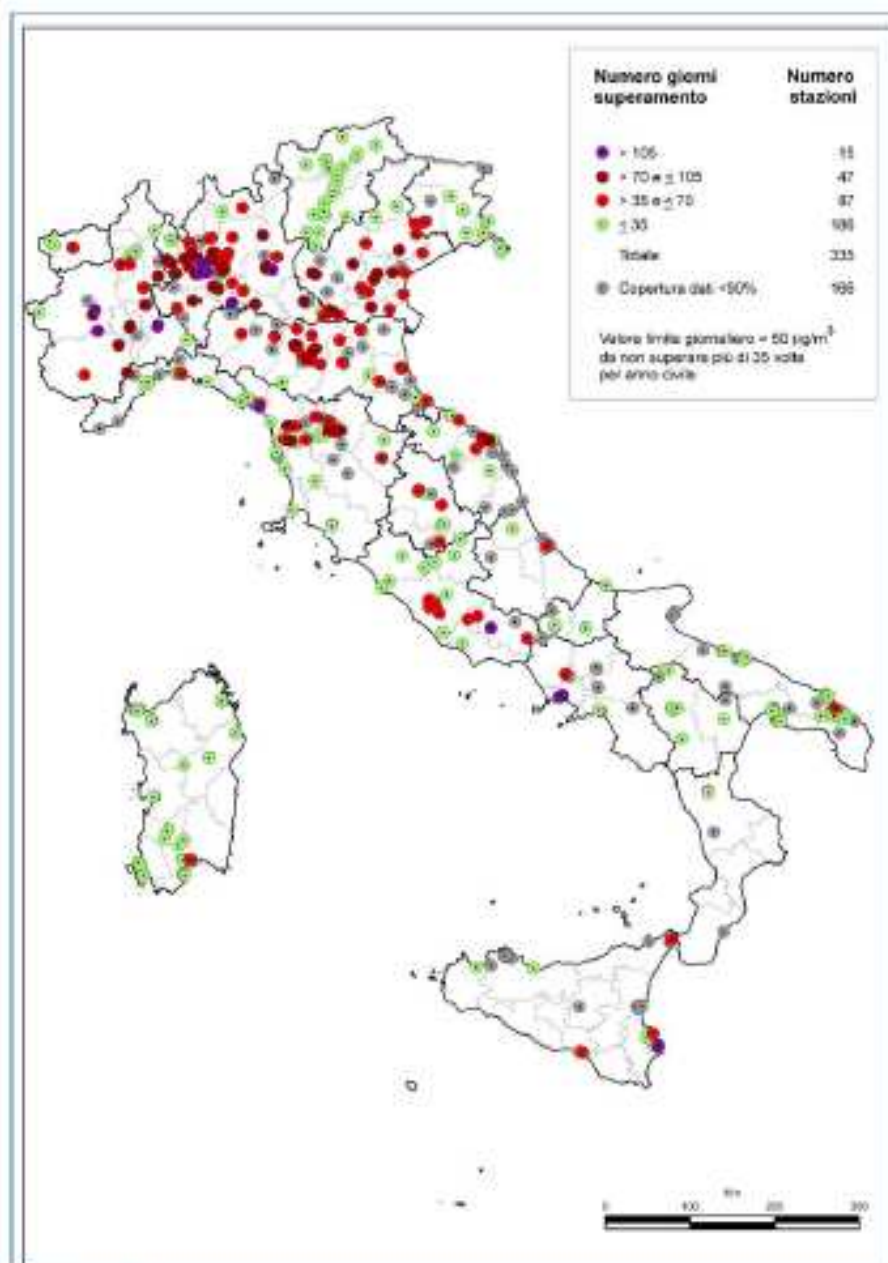
Esempio: Roma PM10 ed NO2



# La geografia dell'inquinamento

- Centraline di monitoraggio
- Osservazioni satellitari
- Osservazioni satellitari + uso del territorio
- Modelli di dispersione
- Uso del territorio → Land use regression

## Sistema monitoraggio PM<sub>10</sub> ISPRA



Fonte: ISPRA

Figura 6.23: PM<sub>10</sub>- Stazioni di monitoraggio per classi del numero giorni di superamento del valore limite giornaliero (50 µg/m<sup>3</sup> da non superare più di 35 volte per anno civile) (2009)

# Osservazioni satellitari



# Global Estimates of Ambient Fine Particulate Matter Concentrations from Satellite-Based Aerosol Optical Depth: Development and Application

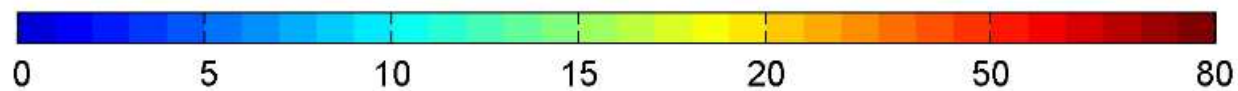
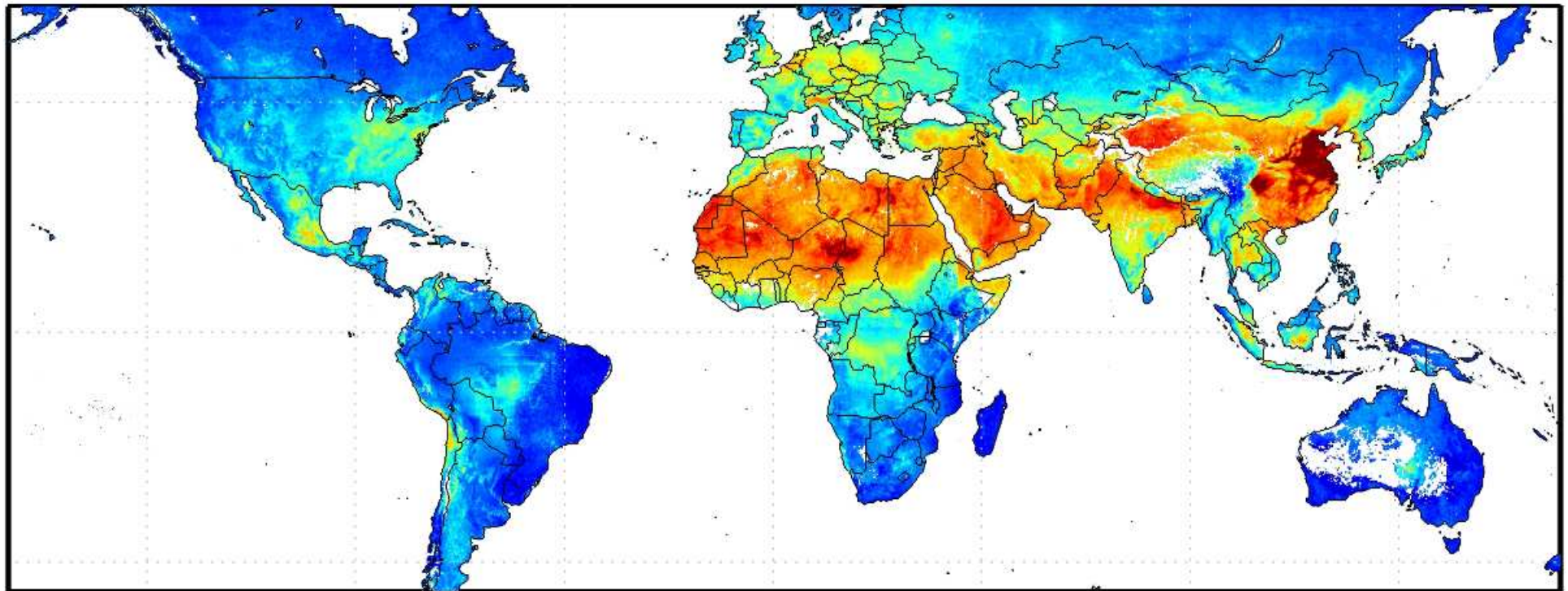
Aaron van Donkelaar,<sup>1</sup> Randall V. Martin,<sup>1,2</sup> Michael Brauer,<sup>3</sup> Ralph Kahn,<sup>4</sup> Robert Levy,<sup>4</sup> Carolyn Verduzco,<sup>1</sup> and Paul J. Villeneuve<sup>5,6</sup>

*Environ Health Perspect* 118:847–855 (2010).

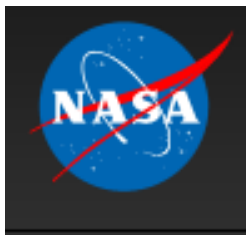
EHP paper of the year

- The study used satellite data gathered over 6 years
- The study Combined data gathered from two different NASA satellite instruments —MODIS (Moderate Resolution Imaging Spectroradiometer) and MISR (Multiangle Imaging Spectroradiometer)—
- The satellite data yield a measurement called aerosol optical depth (AOD), which relates to the total amount of aerosol particles in the air between the ground and the satellite.
- The scientists combined AOD from the two satellites, then applied a chemical-transport model that integrated details about atmospheric structure and chemistry.
- The authors validated this approach by comparing their estimates to those taken from actual sampling performed at the ground level and found a statistically significant level of agreement.





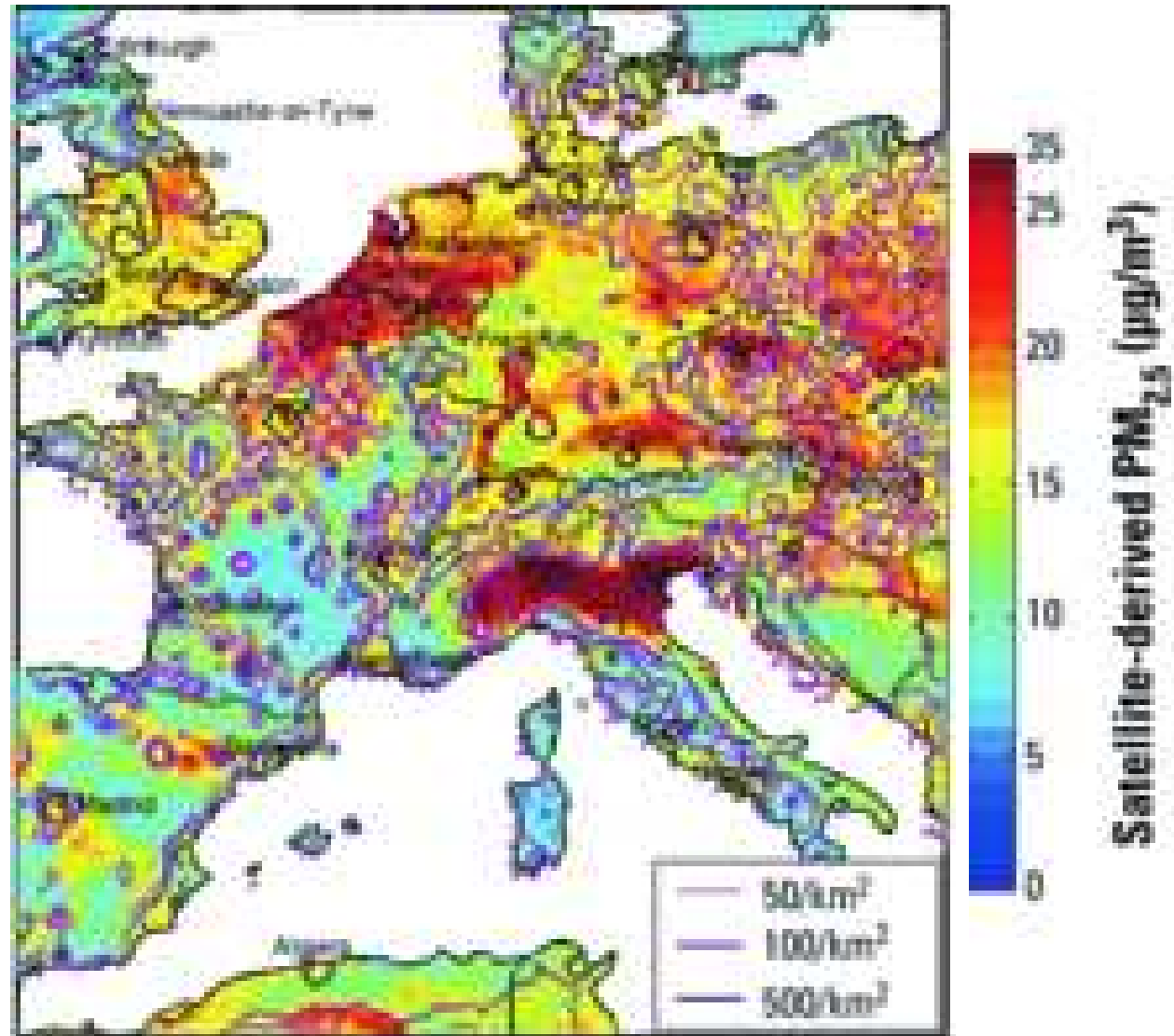
Satellite-Derived PM<sub>2.5</sub> [ $\mu\text{g}/\text{m}^3$ ]



Satellite-derived map of PM<sub>2.5</sub> averaged over 2001-2006. **Credit:** Dalhousie University, Aaron van Donkelaar



## Regional satellite-derived PM<sub>2.5</sub> concentrations.



# European Exposure Models

- Aimed at European cohorts
- Enhanced models/maps for Europe
  - European monitoring network
  - Land use regression
  - 100m resolution
  - Includes accurate road network & satellite data

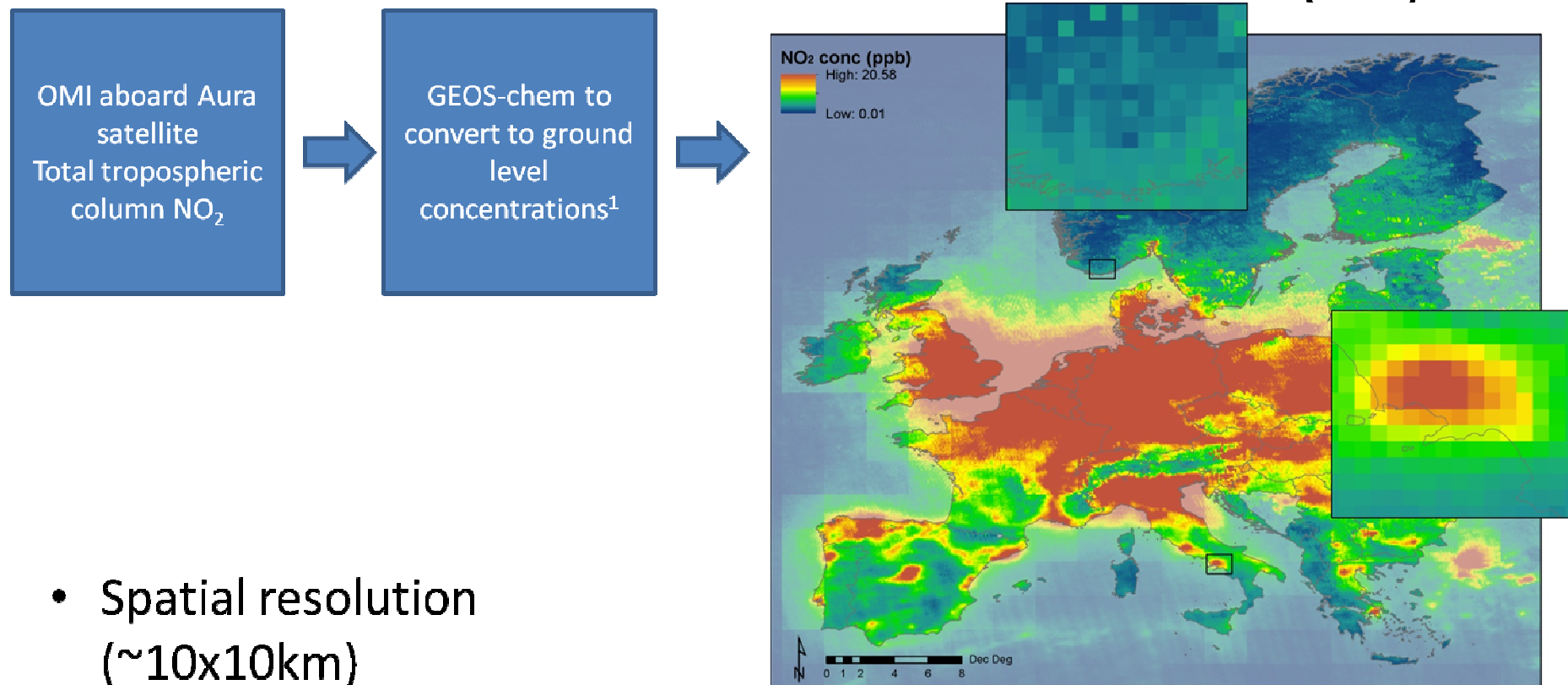
Dr. Danielle Vienneau

MRC-HPA Centre for Environment and Public Health, Imperial College London

With Kees de Hoogh, Gerard Hoek, Matthew Bechle, Eric Novotny, Dylan Millet, Julian Marshall

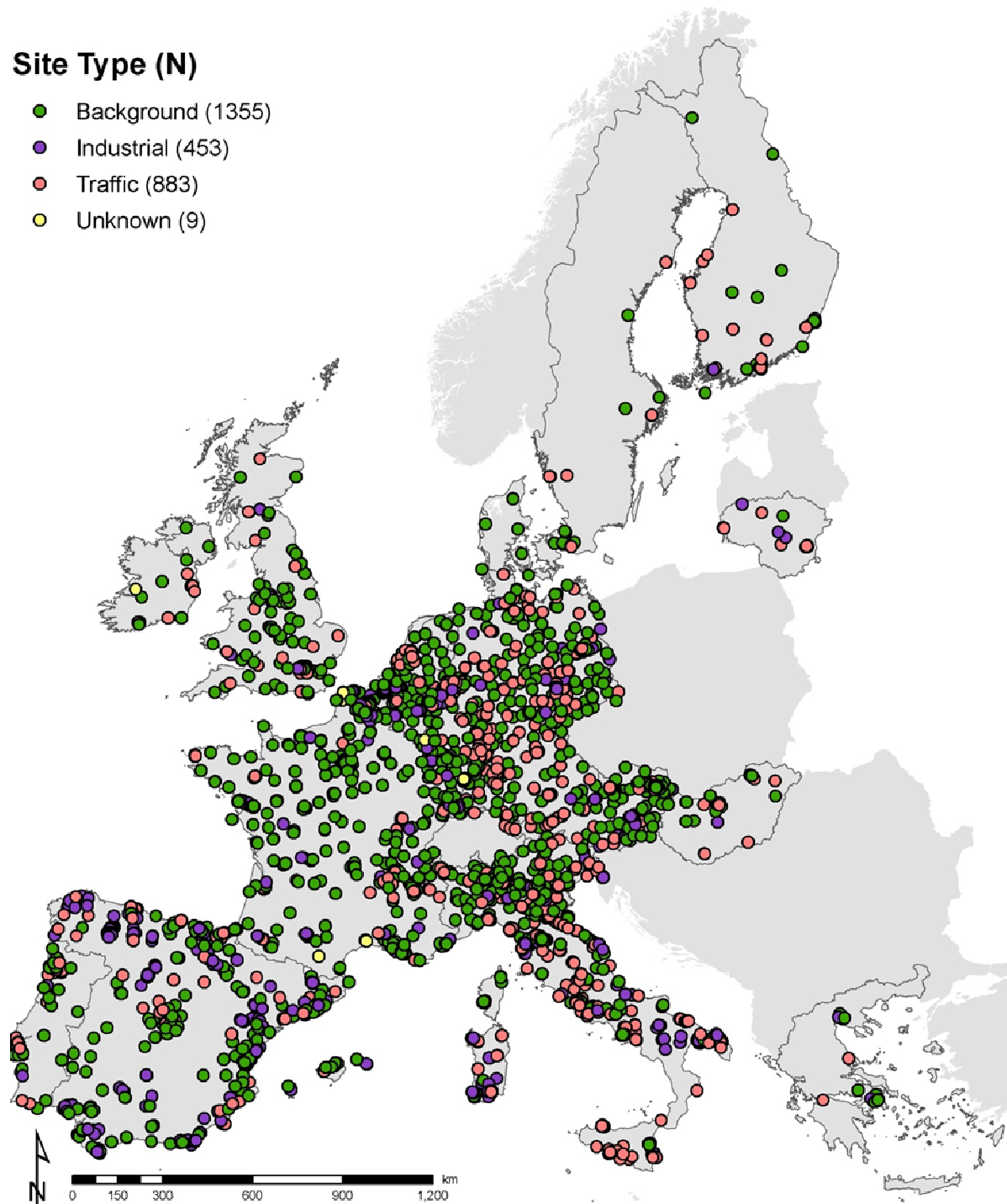
"European NO<sub>2</sub> land use regression incorporating satellite- and ground-based measurements " Presentation at ISEE 2011

# Satellite data (OMI)



## Site Type (N)

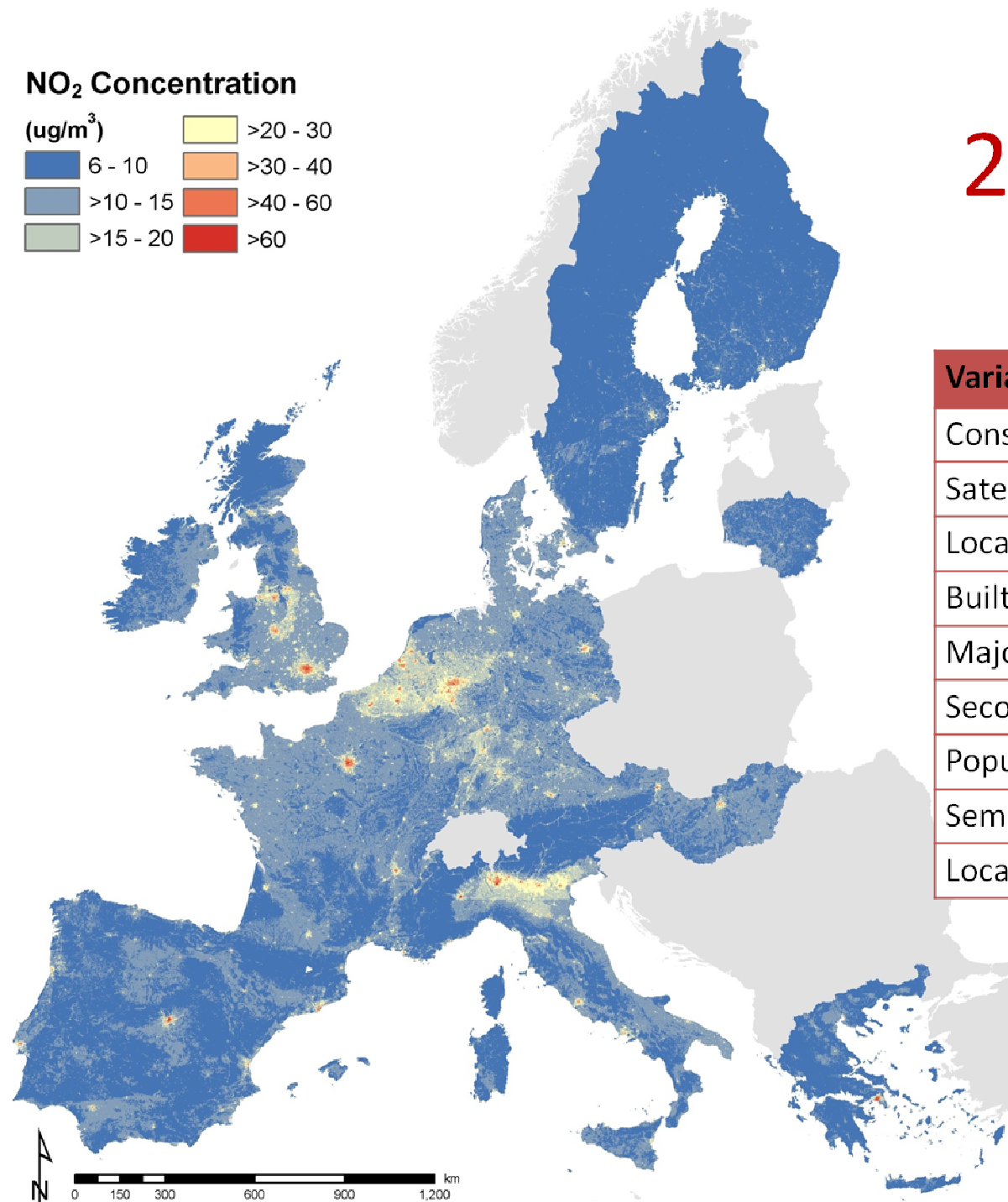
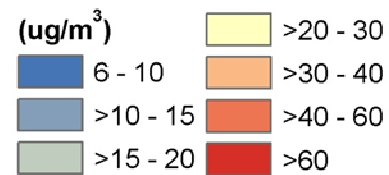
- Background (1355)
- Industrial (453)
- Traffic (883)
- Unknown (9)



# Monitoring

- AIRBASE, annual means,  $\geq 75\%$  data capture
  - 1,987 sites in 2005
  - 2,074 sites in 2006
  - 2,218 sites in 2007
- 80:20 subsets by site type & country

## NO<sub>2</sub> Concentration



# 2005 LUR model

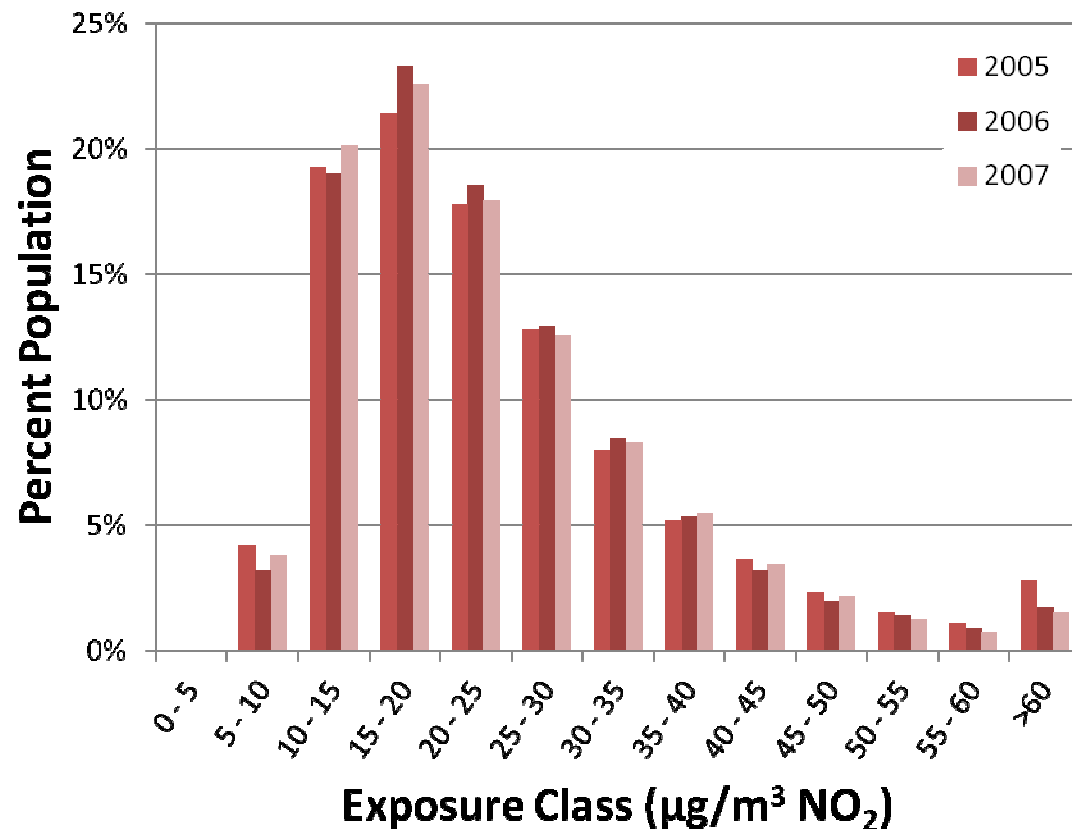
Training (n = 1,584):

Variable	B
Constant	2.29
Satellite NO <sub>2</sub> (ppb)	6.17E-02
Local roads: 2000m	1.05E-06
Built up land: 400m	7.93E-03
Major roads: 100m	5.79E-04
Secondary roads: 2000m	5.99E-06
Population: 100m	1.34E-04
Semi-natural land: 600m	-3.33E-03
Local roads: 2000 - 10000m	1.14E-07

Validation (n = 403):

R <sup>2</sup>	SEE
0.60	10.22

# European exposure profiles



- ~10% people in areas exceeding guideline limit
  - 40 µg/m<sup>3</sup>



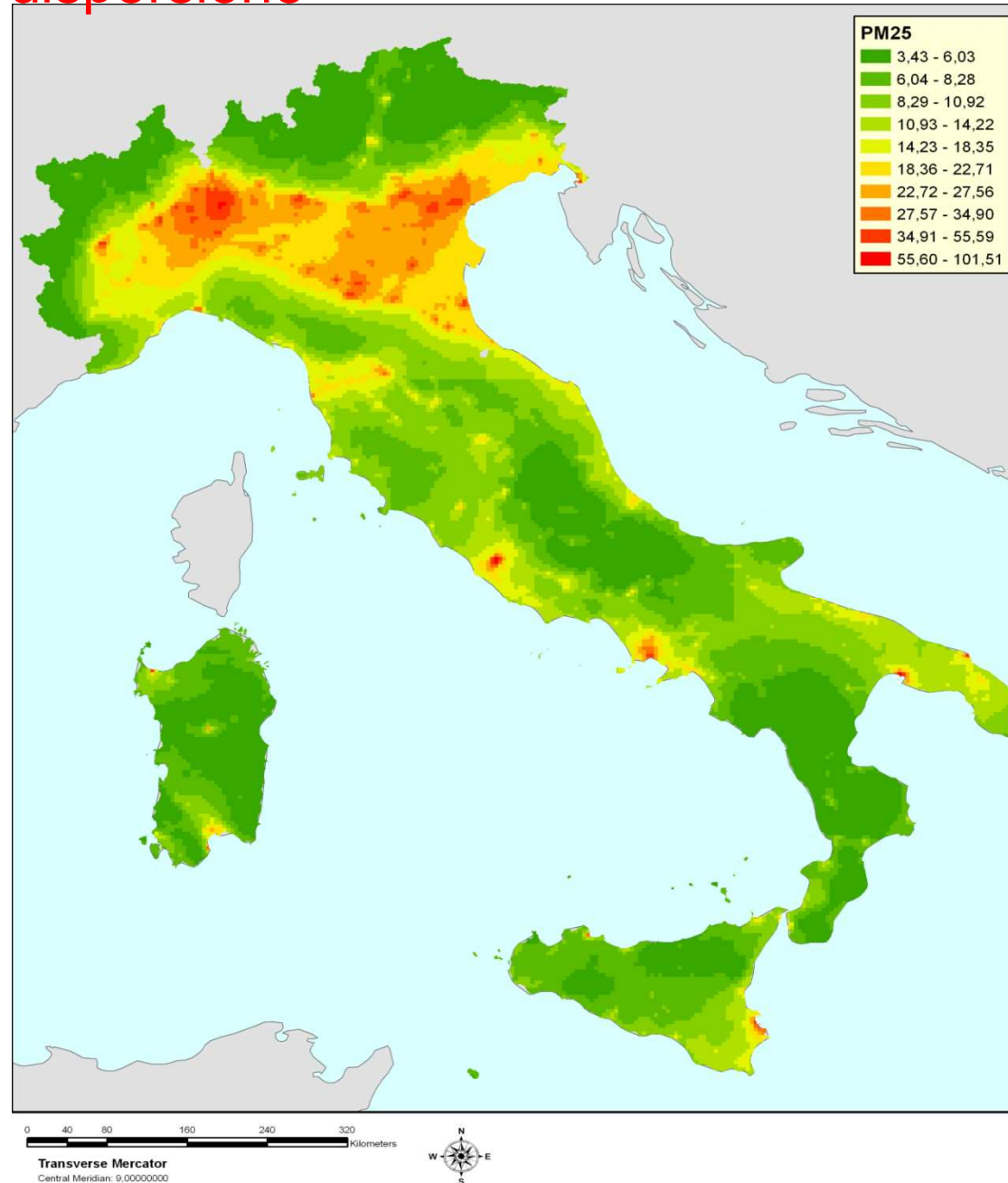
# Modelli di dispersione

Utilizzano dati sulle emissioni, dati meteorologici e topografia per stimare le concentrazioni di inquinanti nello spazio, assumendo un processo deterministico alla base della dispersione nell'aria

# Modello di dispersione

Rappresentazione  
modellistica della  
concentrazione media  
annuale di PM2.5 in  
Italia, griglia 4\*4 km.

Modello MINNI  
(Modello Integrato  
Nazionale). Zanini  
et al. 2011



**Tabella A: PM<sub>2,5</sub> - valore limite di concentrazione ai sensi del D.Lgs 155/10**

	Periodo di mediazione	Valore limite	Margine di tolleranza	Data alla quale il valore limite deve essere raggiunto
<b>FASE 1</b>				
Valore limite annuale	Anno civile	25 µg/m <sup>3</sup>	20 % all'11 giugno 2008, con riduzione il 1 gennaio successivo e successivamente ogni 12 mesi secondo una percentuale annua costante fino a raggiungere lo 0 % entro il 1° gennaio 2015	1° gennaio 2015
<b>FASE 2</b>				
Valore limite annuale	Anno civile	20 µg/m <sup>3</sup>		1° gennaio 2020

## Distribuzione relativa della popolazione Italiana per livelli di PM2.5

	ITALIA		NORD		CENTRO		SUD		ISOLE	
PM 2.5 ug/mc	N	%	N	%	N	%	N	%	N	%
<10	12,470,745	21.9	2,985,532	10.7	2,962,236	27.3	3,047,953	26.0	3,475,024	52.7
1-20	21,746,042	38.1	7,914,867	28.4	5,614,702	51.7	5,870,367	50.1	2,346,106	35.6
20-25	8,445,034	14.8	5,695,262	20.5	1,016,326	9.4	1,293,077	11.0	440,369	6.7
>25	14,348,312	25.2	11,240,510	40.4	1,260,255	11.6	1,510,840	12.9	336,707	5.1
	57,010,133	100.0	27,836,171	100.0	10,853,519	100.0	11,722,237	100.0	6,598,206	100.0

Modello di dispersione MINNI + GIS Italia ISTAT 2001



## RESEARCH

## Open Access

# Mortality and morbidity among people living close to incinerators: a cohort study based on dispersion modeling for exposure assessment

Andrea Ranzi<sup>1†</sup>, Valeria Fano<sup>2†</sup>, Laura Erspamer<sup>1</sup>, Paolo Lauriola<sup>1</sup>, Carlo A Perucci<sup>2</sup> and Francesco Forastiere<sup>2\*</sup>

## Abstract

**Background:** Several studies have been conducted on the possible health effects for people living close to incinerators and well-conducted reviews are available. Nevertheless, several uncertainties limit the overall interpretation of the findings. We evaluated the health effects of emissions from two incinerators in a pilot cohort study.

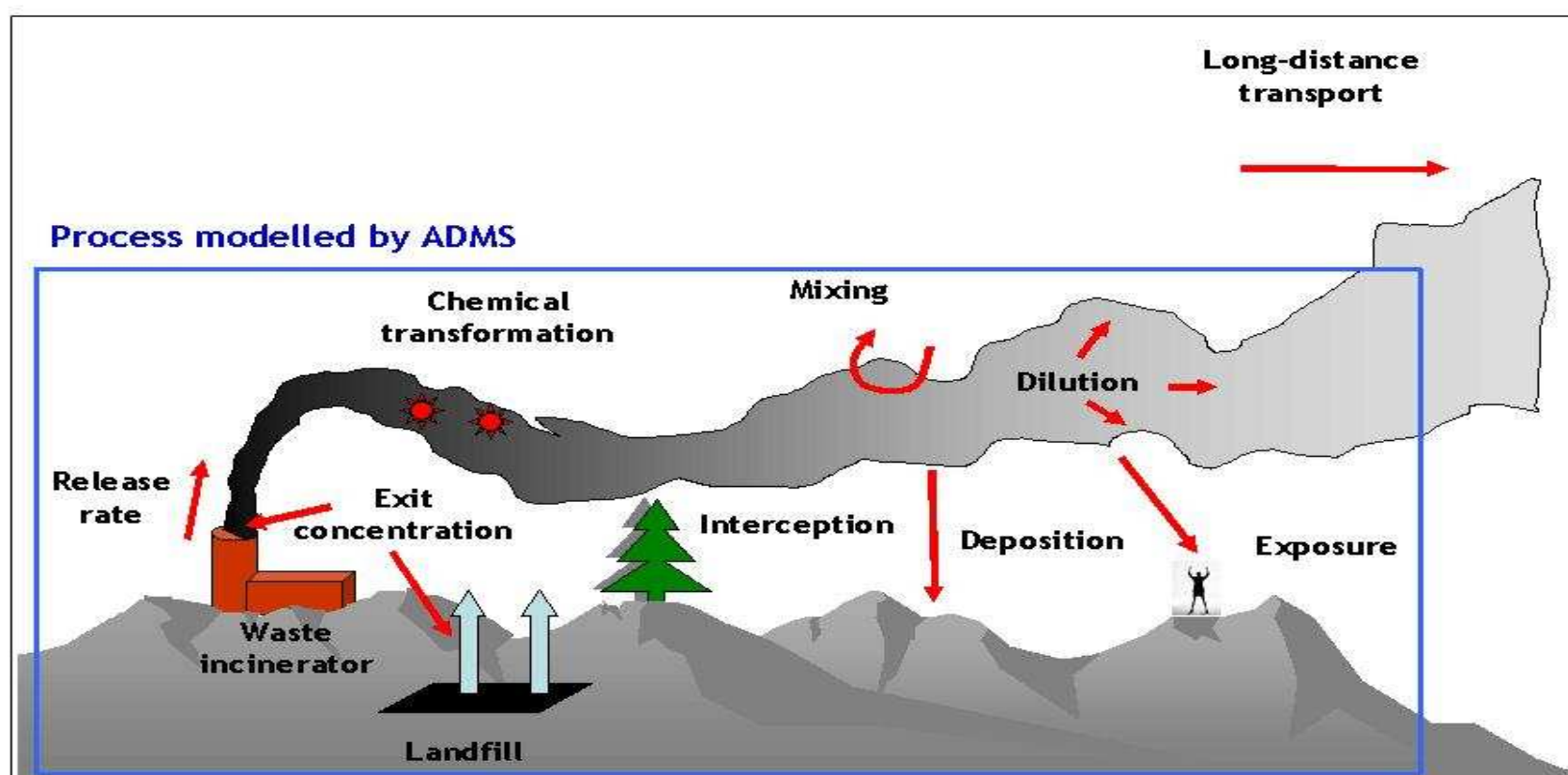
**Methods:** The study area was defined as the 3.5 km radius around two incinerators located near Forlì (Italy). People who were residents in 1/1/1990, or subsequently became residents up to 31/12/2003, were enrolled in a longitudinal study (31,347 individuals). All the addresses were geocoded. Follow-up continued until 31/12/2003 by linking the mortality register, cancer registry and hospital admissions databases. Atmospheric Dispersion Model System (ADMS) software was used for exposure assessment; modelled concentration maps of heavy metals (annual average) were considered the indicators of exposure to atmospheric pollution from the incinerators, while concentration maps of nitrogen dioxide (NO<sub>2</sub>) were considered for exposure to other pollution sources. Age and area-based socioeconomic status adjusted rate ratios and 95% Confidence Intervals were estimated with Poisson regression, using the lowest exposure category to heavy metals as reference.

**Results:** The mortality and morbidity experience of the whole cohort did not differ from the regional population. In the internal analysis, no association between pollution exposure from the incinerators and all-cause and cause-specific mortality outcomes was observed in men, with the exception of colon cancer. Exposure to the incinerators was associated with cancer mortality among women, in particular for all cancer sites (RR for the highest exposure level = 1.47, 95% CI: 1.09, 1.99), stomach, colon, liver and breast cancer. No clear trend was detected for cancer incidence. No association was found for hospitalizations related to major diseases. NO<sub>2</sub> levels, as a proxy from other pollution sources (traffic in particular), did not exert an important confounding role.

**Conclusions:** No increased risk of mortality and morbidity was found in the entire area. The internal analysis of the cohort based on dispersion modeling found excesses of mortality for some cancer types in the highest exposure categories, especially in women. The interpretation of the findings is limited given the pilot nature of the study.

# Modelli di dispersione

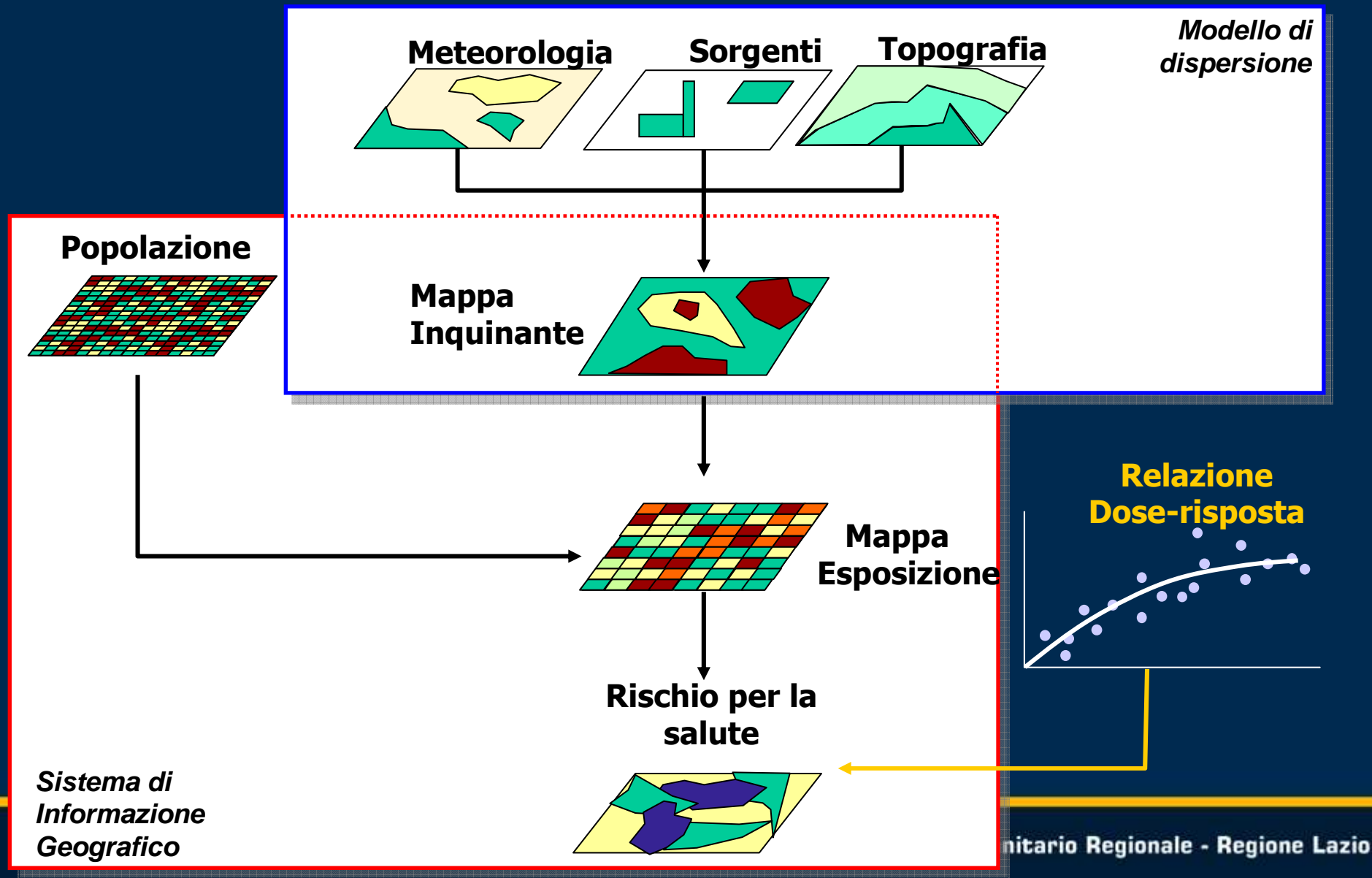
- Caratteristiche dell'impianto
- Condizioni meteorologiche
- Caratteristiche topografiche



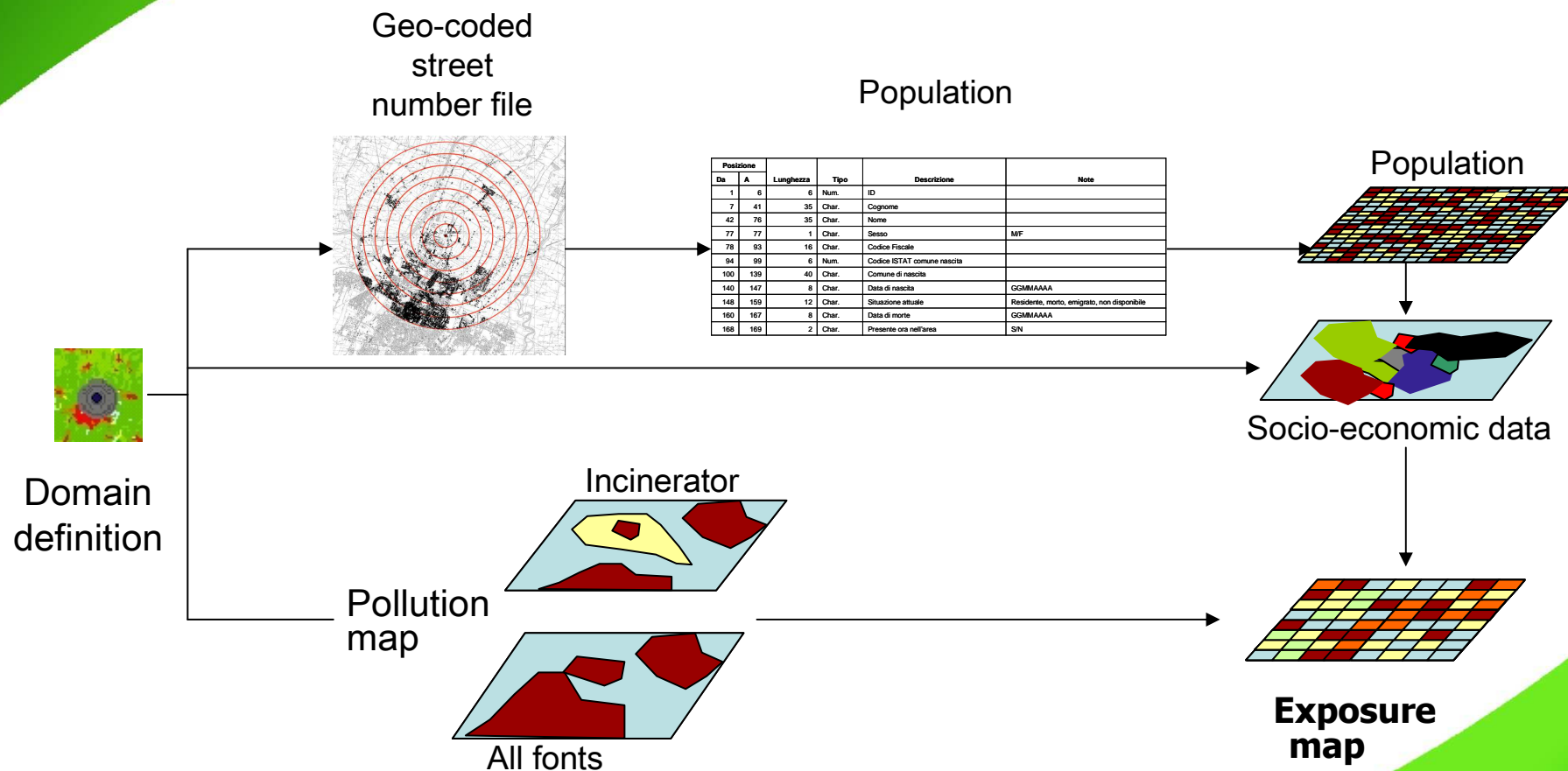




# Schema riassuntivo dello studio epidemiologico ambiente - salute



# Disegno studio epidemiologico

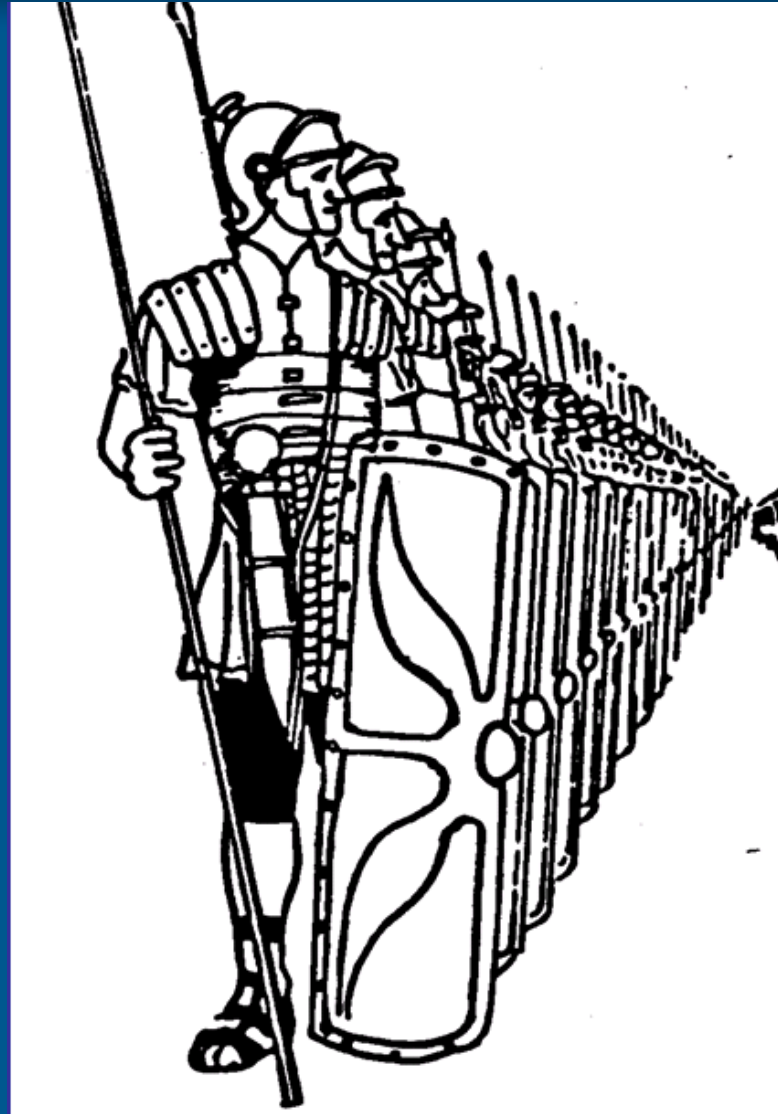


# Cohort

It comes from Latin  
"cohors":

Division of Roman soldiers  
("Originally, the cohort  
was a sub-unit of a Roman  
legion, usually consisting  
of 480 legionaries  
including six centurions")

A group of people sharing  
a specific feature and  
progressing throughout  
time



# Studio epidemiologico Coriano (Forlì)

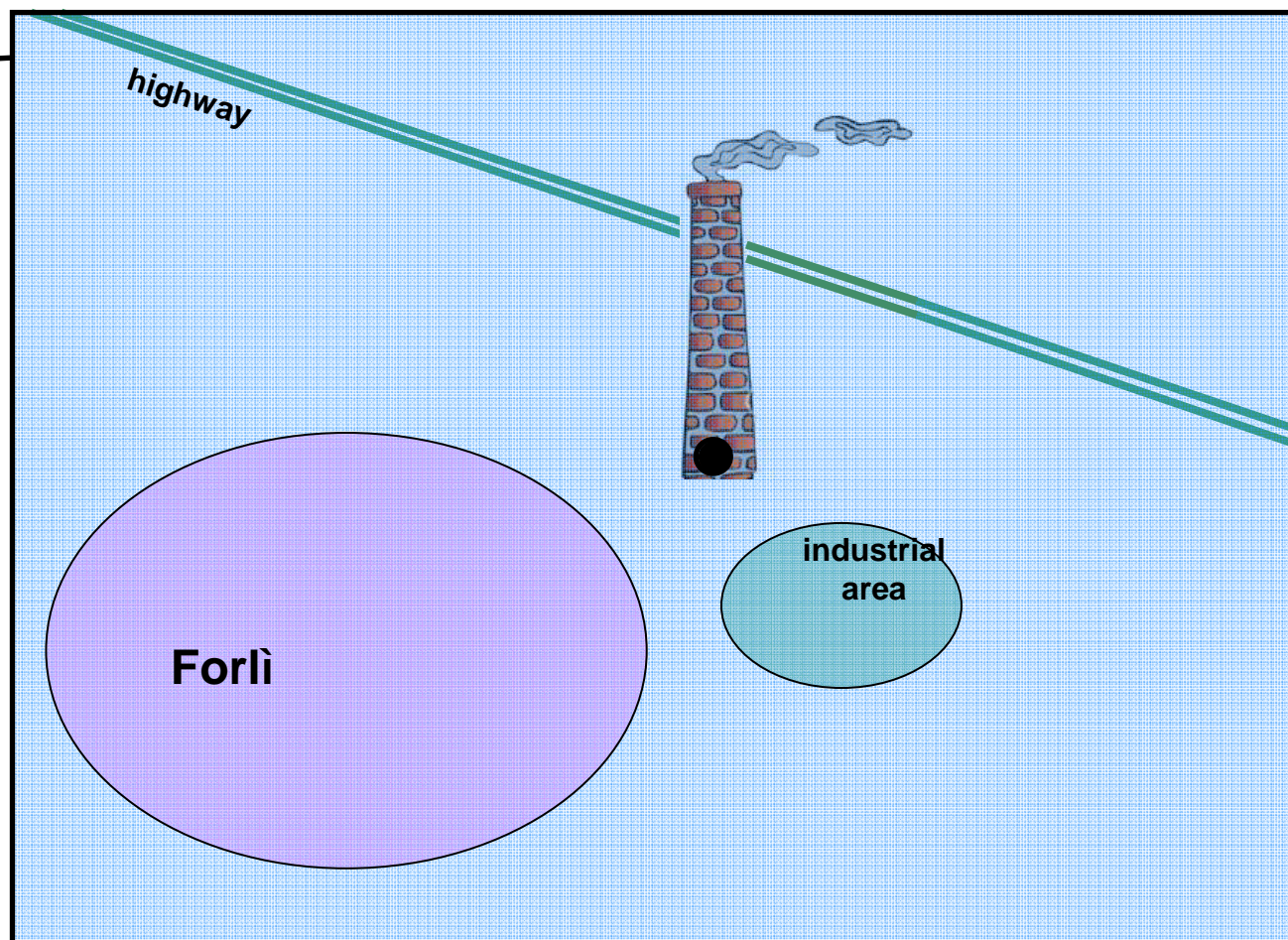
## Coriano (Forlì)



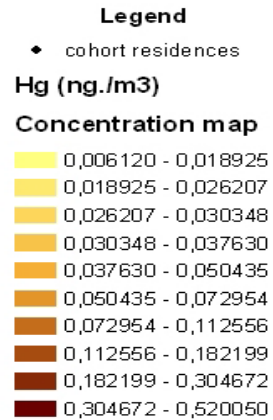
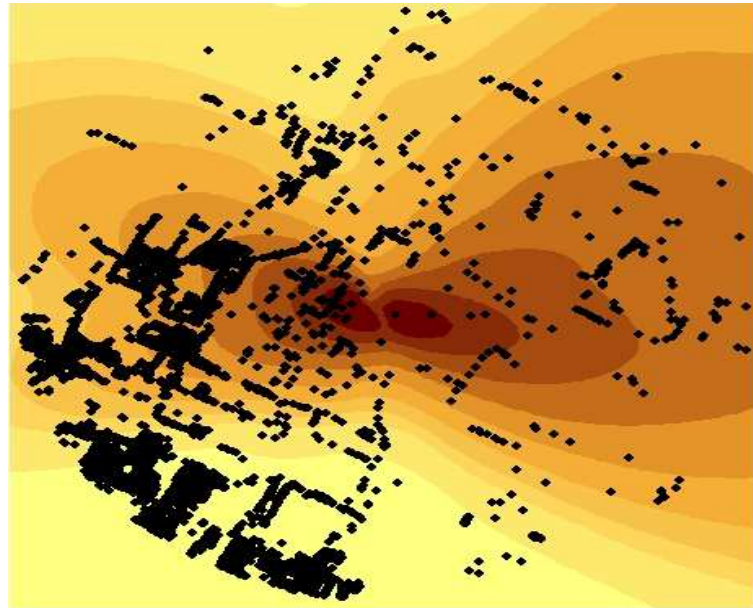
Emilia Romagna

**Coorte di  
popolazione**

**1990-2003**

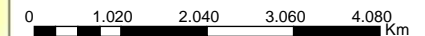
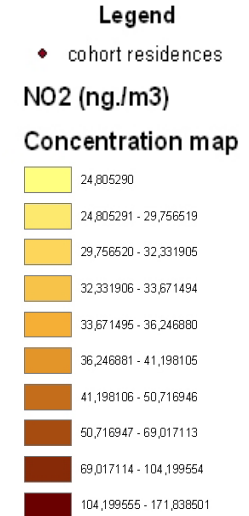
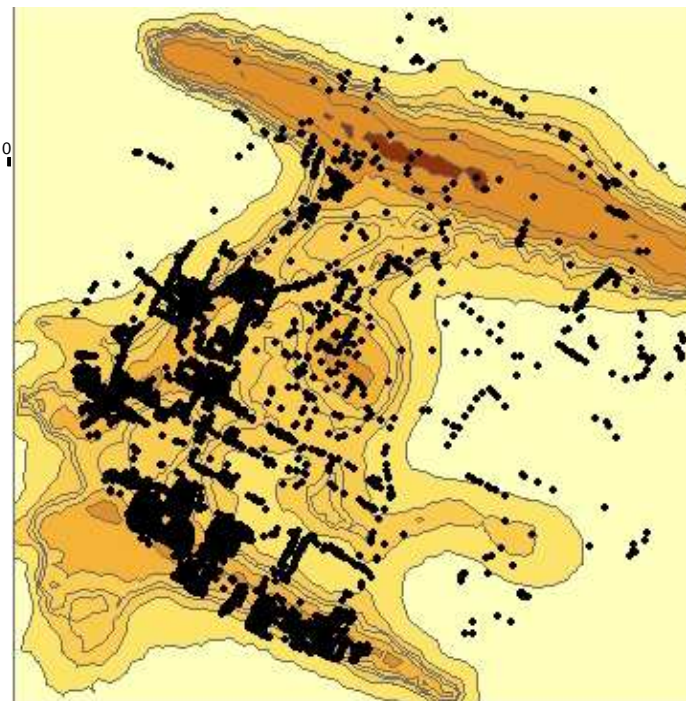


# Risultati modelli di dispersione (ADMS)



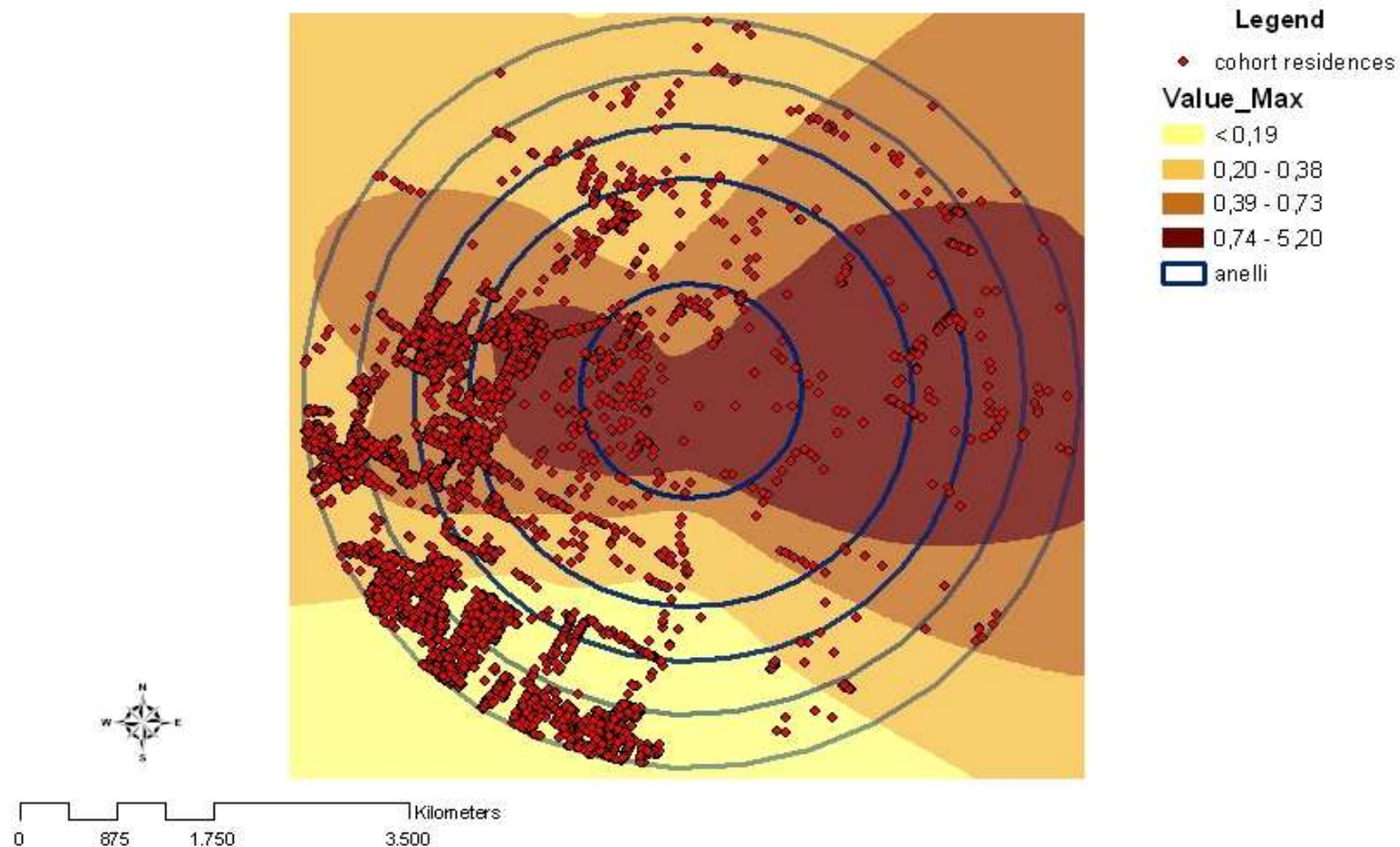
**Incineritore**

**Tutte le fonti**





## Risultati modello di dispersione da inceneritori e coorte di popolazione, Coriano (Forlì)





# Inquinanti da inceneritori e mortalità nelle donne (Coriano)

Causa (ICD-9)	Hg (ng/m <sup>3</sup> )	OSS	RR	<u>IC 95%</u>		RR <sub>SES</sub>	<u>IC 95%</u>	
Tutte le cause (0-999)	<0.19	587	1.00	-	-	1.00	-	-
	0.20-0.38	546	1.11	0.98	1.24	1.11	0.99	1.25
	0.39-0.73	511	1.10	0.98	1.24	1.11	0.98	1.25
	0.74-5.20	177	1.21 *	1.02	1.43	1.21 *	1.02	1.43
Tumori totali (140-239)	<0.19	180	1.00	-	-	1.00	-	-
	0.20-0.38	156	1.08	0.87	1.34	1.08	0.87	1.34
	0.39-0.73	171	1.21	0.98	1.49	1.25 *	1.01	1.55
	0.74-5.20	61	1.33	0.99	1.77	1.39 *	1.03	1.87



# ERAS Lazio

EPIDEMIOLOGIA RIFIUTI  
AMBIENTE E SALUTE



[GUIDA AL SITO](#) [HOME](#) [IL PROGRAMMA](#) [GLOSSARIO](#) [IMPIANTI](#) [LINK](#)

CERCA

## RIFIUTI



Produzione  
Raccolta e gestione  
Impianti  
La normativa

## AMBIENTE



Conoscenze scientifiche  
Territorio  
Stato dell'ambiente  
Controlli e monitoraggi ambientali  
Valutazione della qualità dell'aria

## SALUTE



Conoscenze scientifiche  
Metodologia  
Comuni interessati  
Popolazione esposta  
Effetti sulla salute

## NEWS

25- Mar- 11

[Mortalità e morbidità in persone che vivono nei pressi di un inceneritore: uno studio di coorte](#)

23- Mar- 11

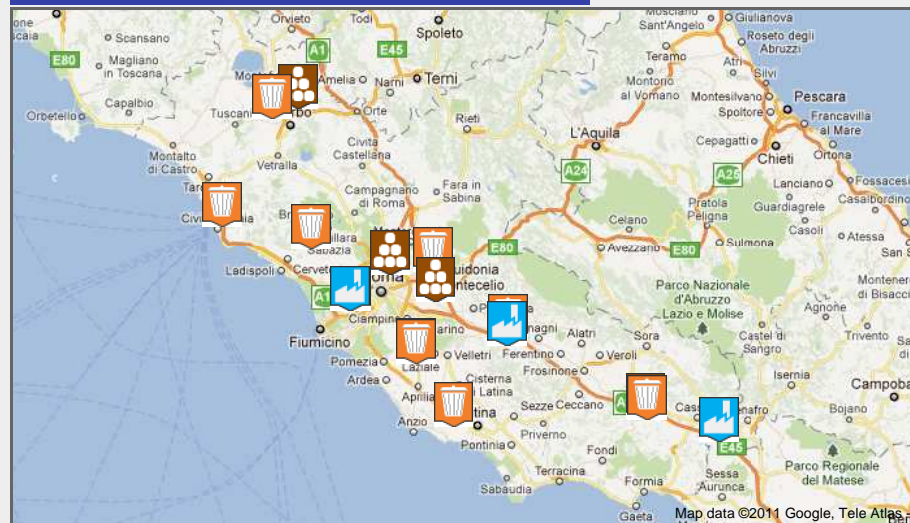
[A Pisa un convegno sulla salute dei lavoratori nel settore rifiuti](#)

15- Mar- 11

[Uno studio sulle emissioni di inquinanti in aria di una discarica](#)

[1](#) [2](#)

## GLI IMPIANTI DI RECUPERO, TRATTAMENTO E SMALTIMENTO NEL LAZIO



### DISCARICHE

[Albano Laziale, Cecchina](#)  
[Bracciano, Cupinoro](#)  
[Civitavecchia, Fosso Crepacuore](#)  
[Colleferro, Colle Fagiolaria](#)  
[Guidonia Montecelio, Inviolata](#)  
[Latina, Borgo Montello](#)  
[Roccasecca, Cerreto](#)  
[Viterbo, Le Fornaci](#)

### TMB-PRODUZIONE DEL CDR

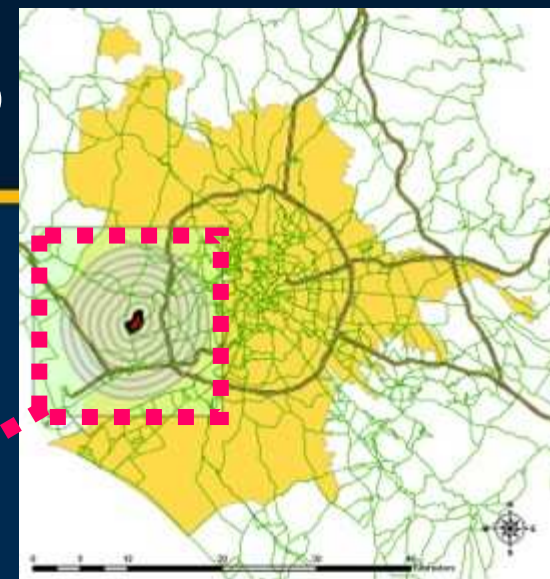
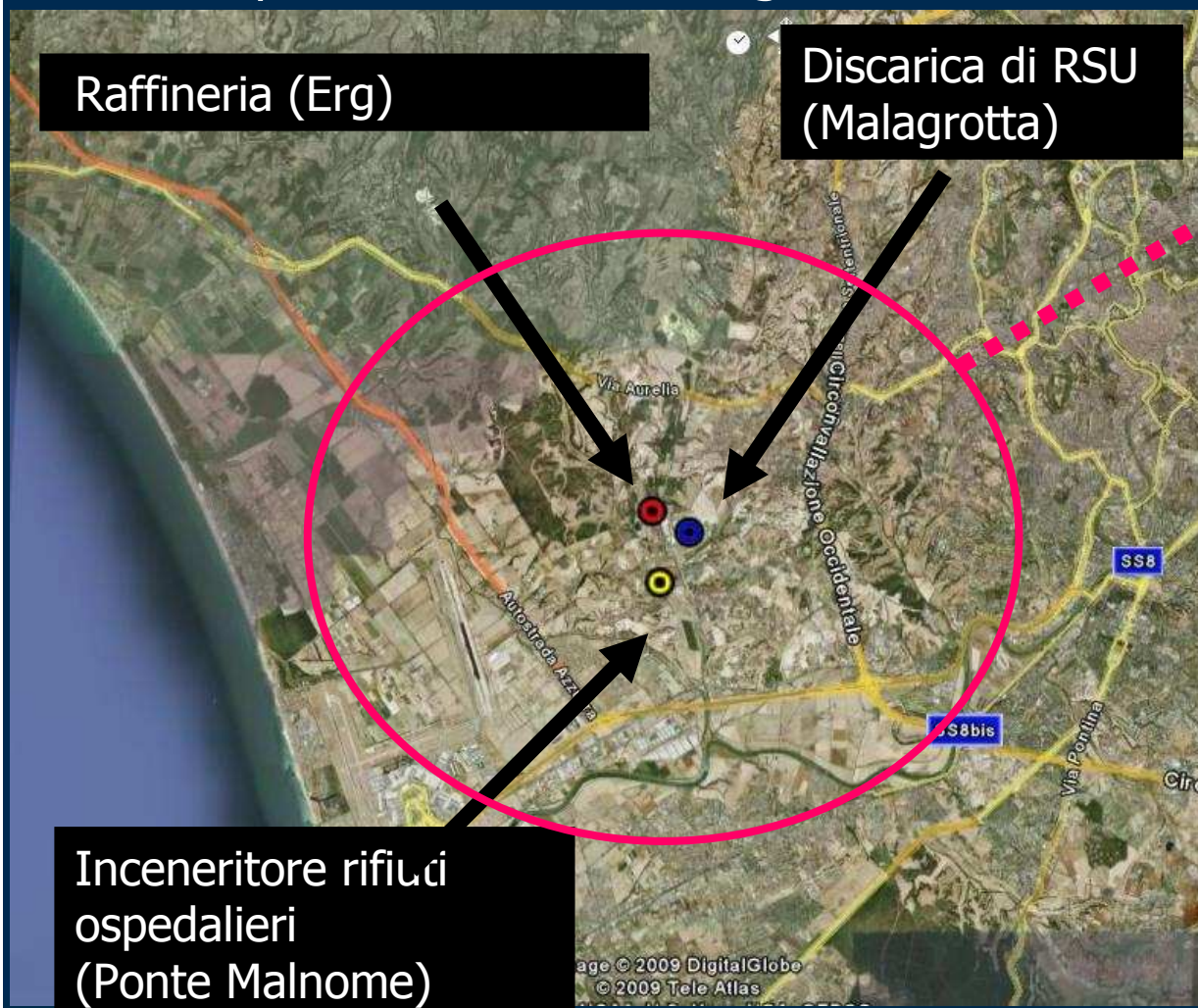
[Albano Laziale, Cecchina](#)  
[Colferrato, S. P. Ortella](#)  
[Roma, Rocca Cencia](#)  
[Roma, Via Salaria](#)  
[Viterbo, Casale Bussi](#)

### INCENERITORI-GASSIFICATORI



# Malagrotta: area in studio

Impianti in attività dagli anni '90



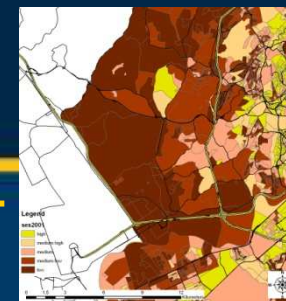
Roma

dominio di  
raggio pari a  
7 km

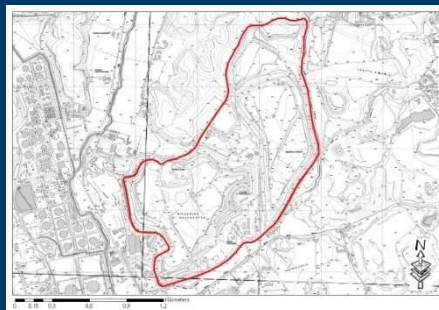




## Activities

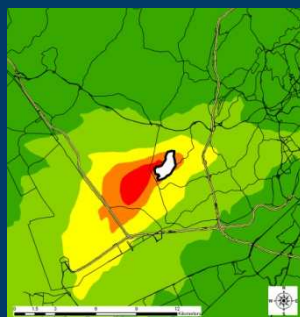
[illegible]

## Socio-economic position index

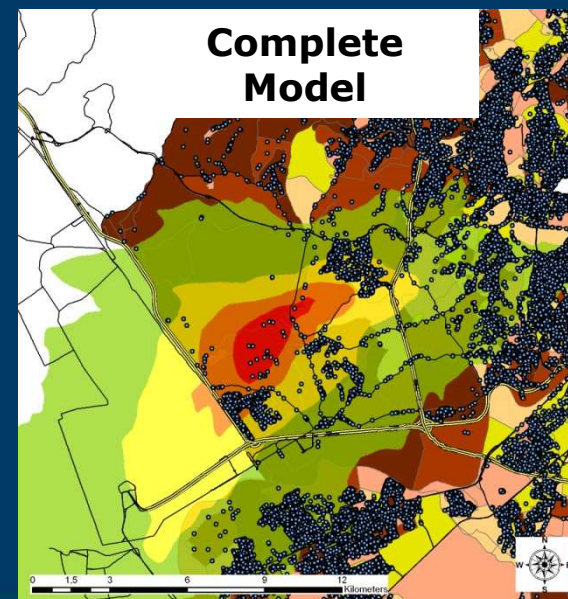


## Study area

# Dispersion models



## Complete Model





# Caratterizzazione della esposizione a sorgenti emissive di tipo areale e puntuale

a



Autostrade

 Buffer 7km





# Emissioni dalla discarica



## Modello LandGEM (Landfill Gas Emissions Model)

### Input

*anno di studio: 2005*

*Periodo attività lotto*

*Tonnellate rifiuto / anno*

### Output

*Totale  
emissioni  
(t / anno)*



*sostanza tracciante:  
 $H_2S$   $\mu g/m^3$*



# Emissioni da sorgenti puntuali

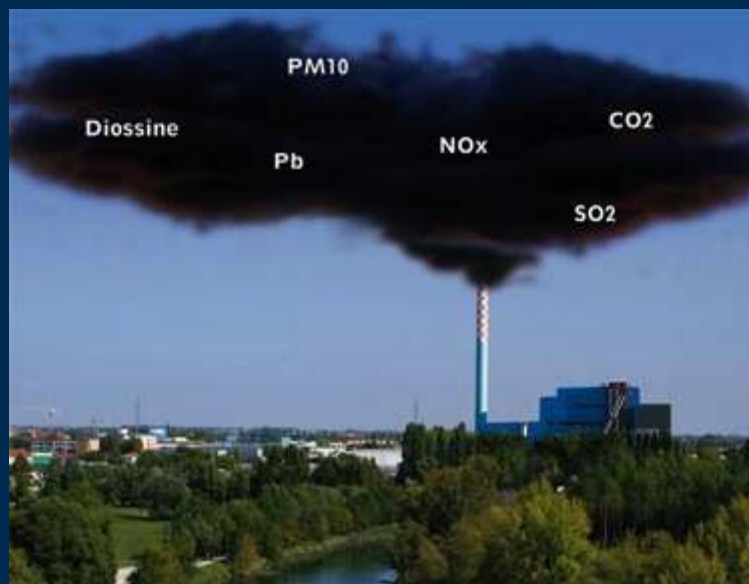


*anno di studio: 2005*

*Periodo attività*

*Totale  
emissioni  
(t / anno)*

*sostanza tracciante:*



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

*Raffineria Petrolchimica*

*PM<sub>10</sub>  $\mu\text{g}/\text{m}^3$*

*Inceneritore*

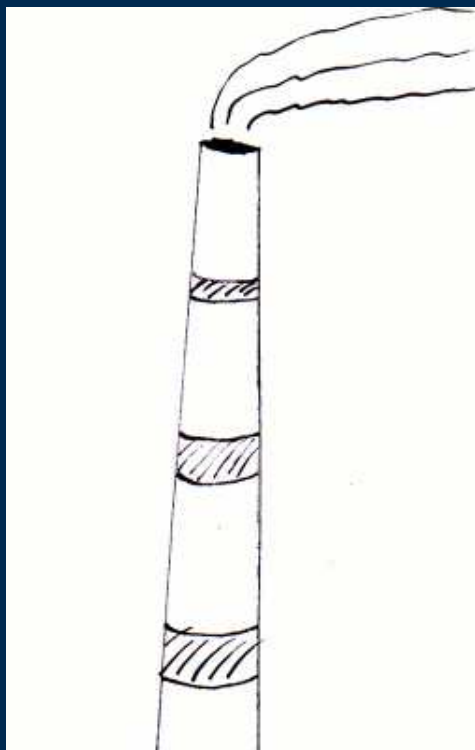


# Modulazione oraria delle emissioni da sorgente puntuale



## Modello EMMA (EMission MAnager)

### Input



*Altezza del camino (m)*  
*Temperatura dei fumi (°C)*  
*Diametro del camino (m)*  
*Velocità di uscita dei fumi (m/s)*  
*Modulazione temporale (oraria)*  
*Localizzazione del camino*  
*Totale emissioni annue ( $\mu\text{g}/\text{m}^3$ )*

### Output

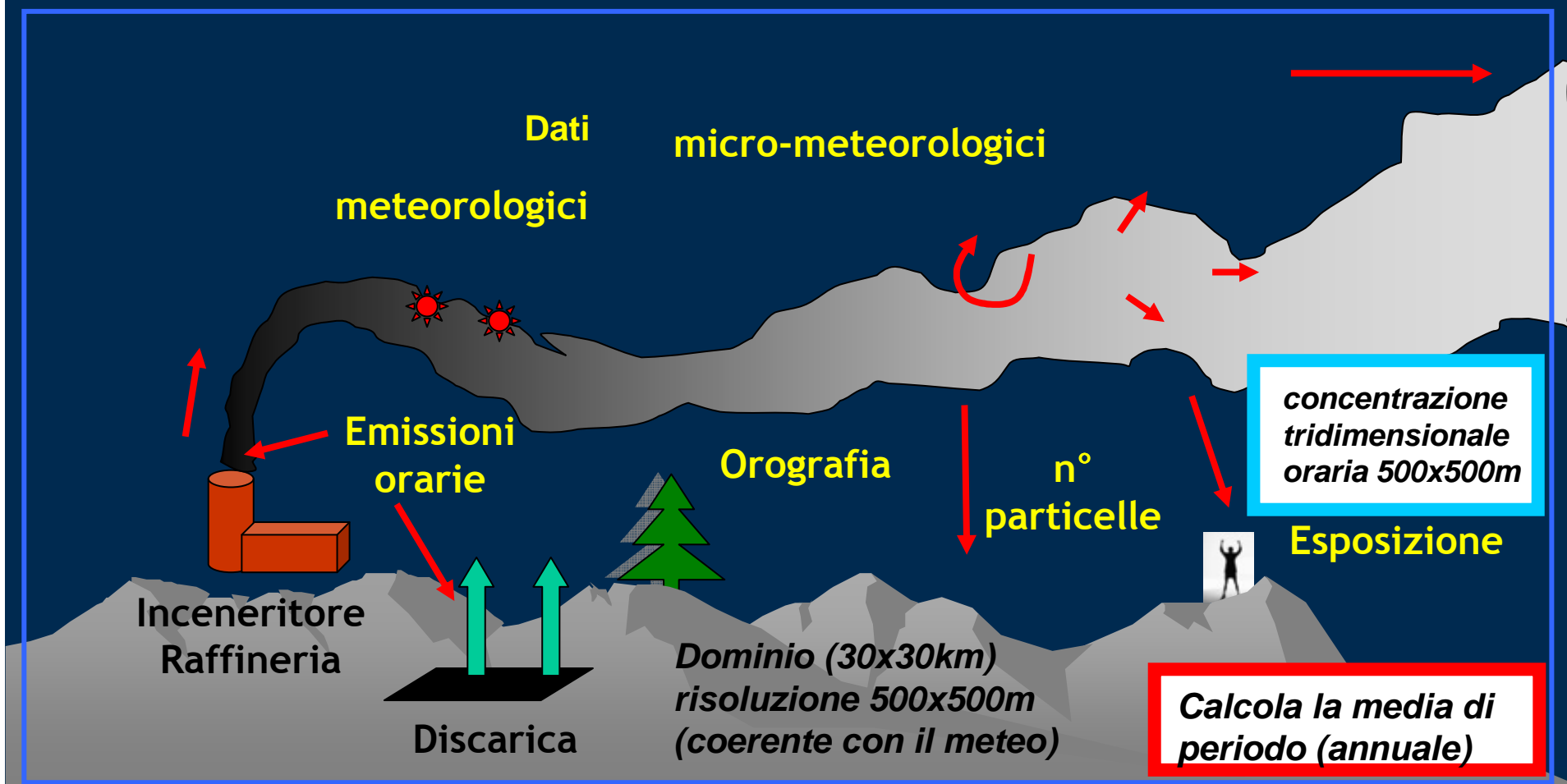
*Emissioni  
orarie*



# Modello di dispersione: SPRAY - Lagrangian particle dispersion model

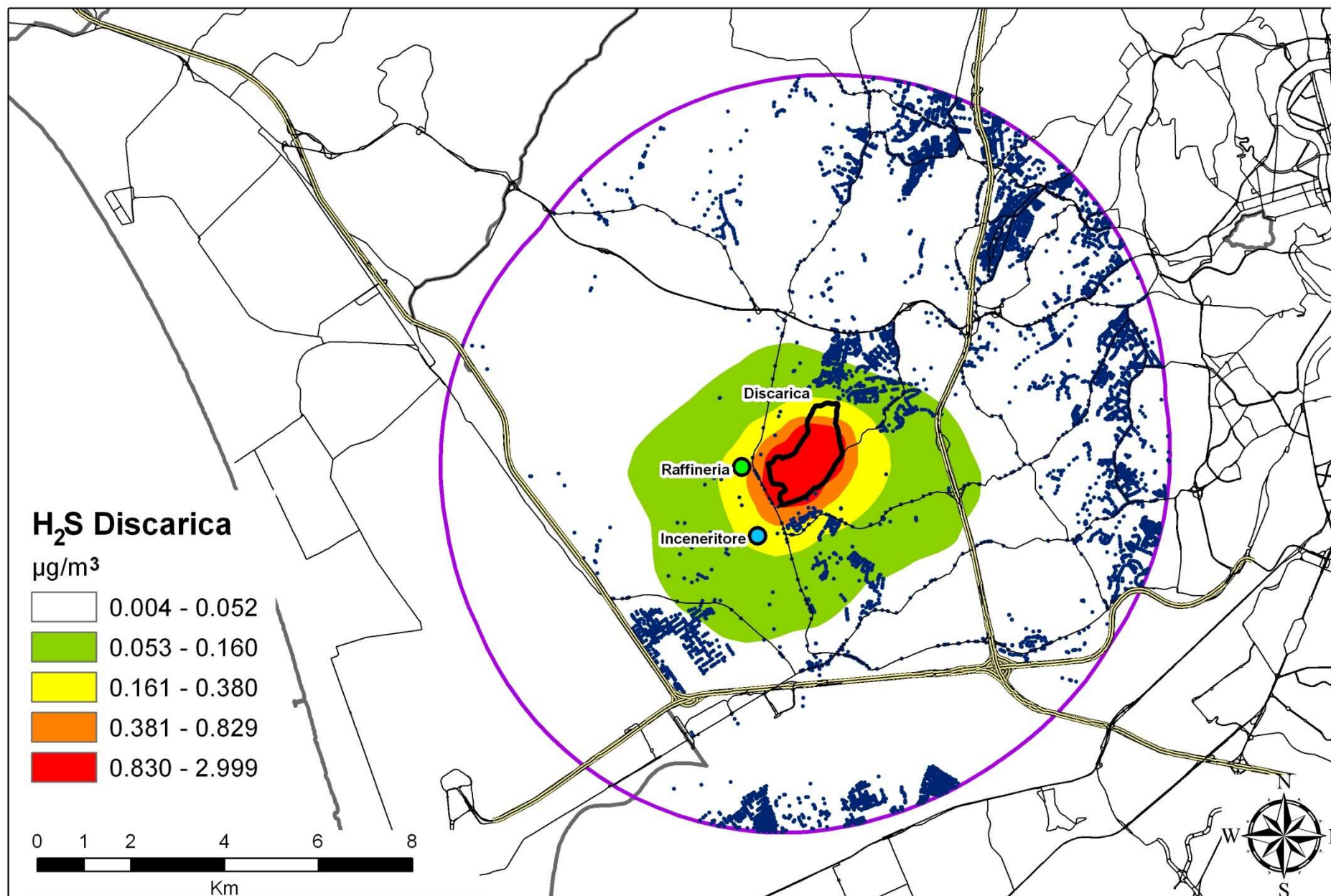
Processo per il calcolo delle concentrazioni

Trasporto a  
lunga distanza

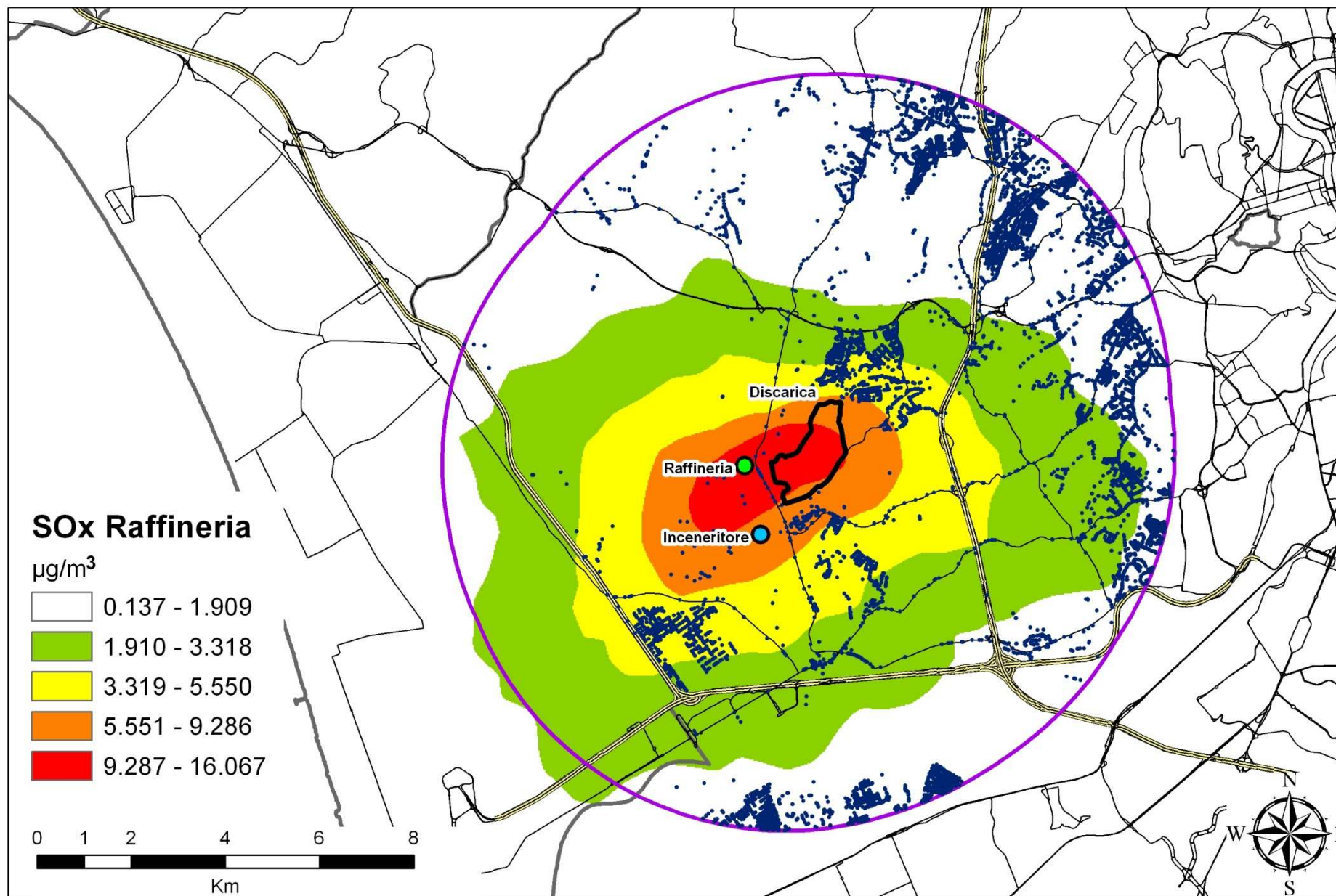




b

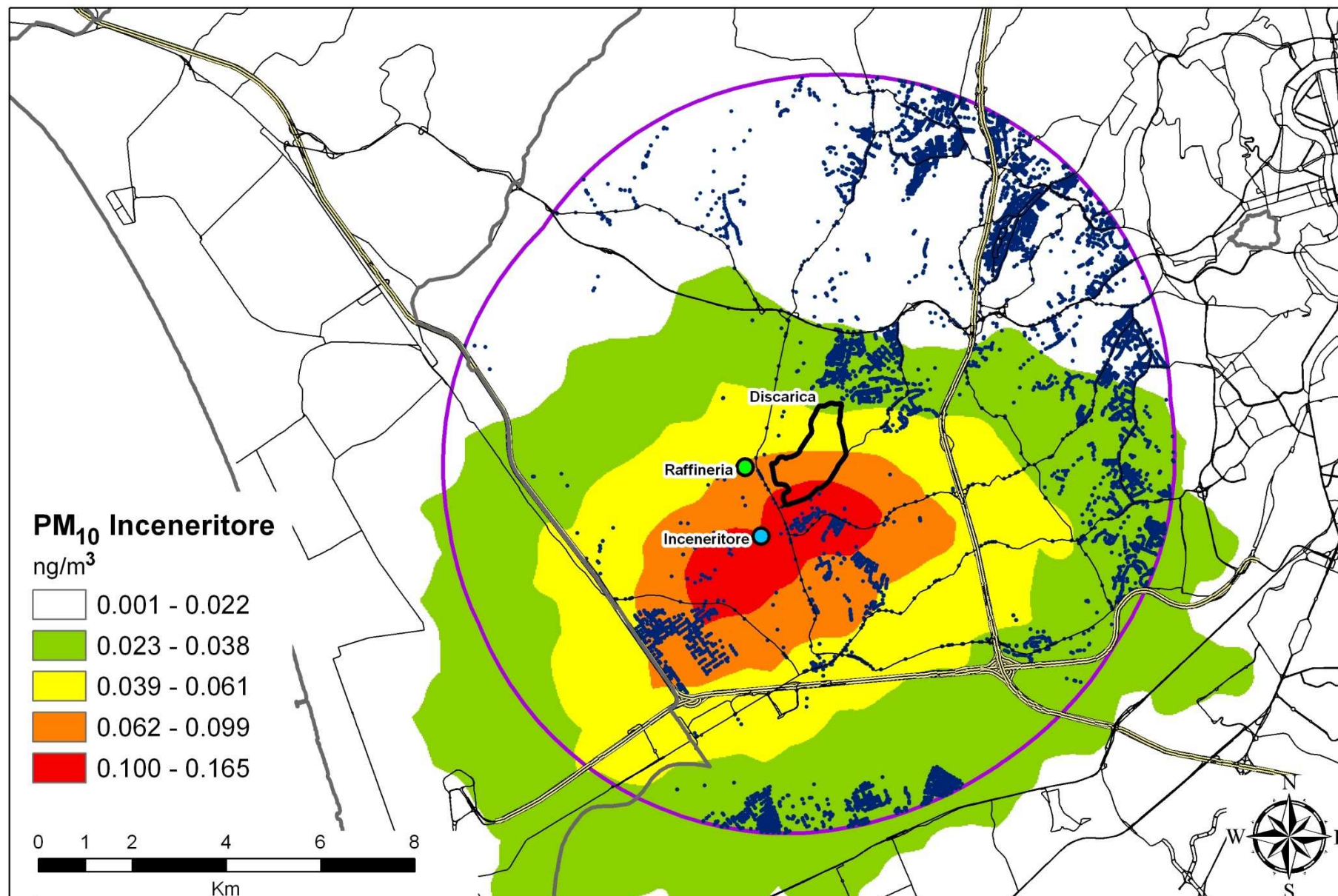


C



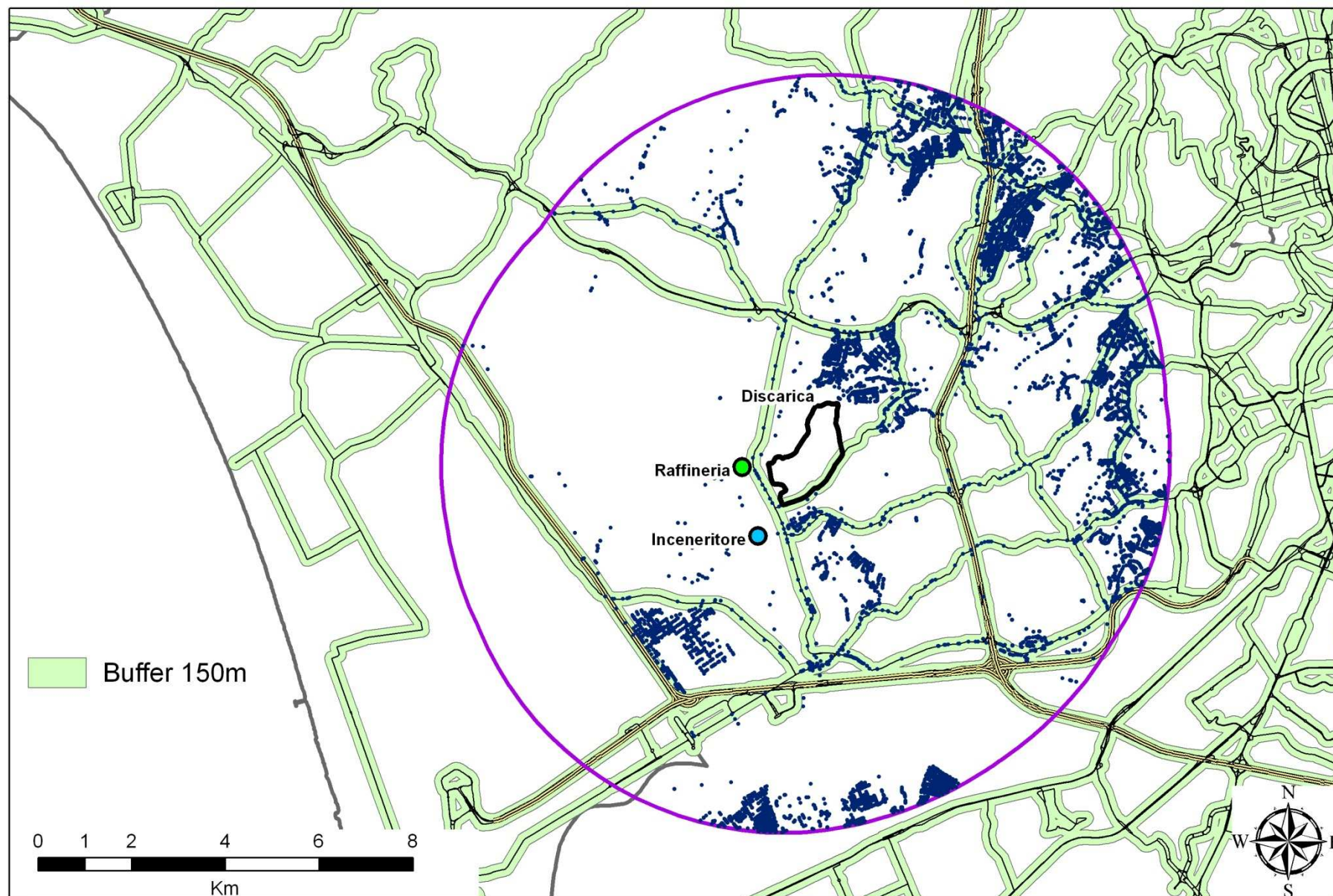


d



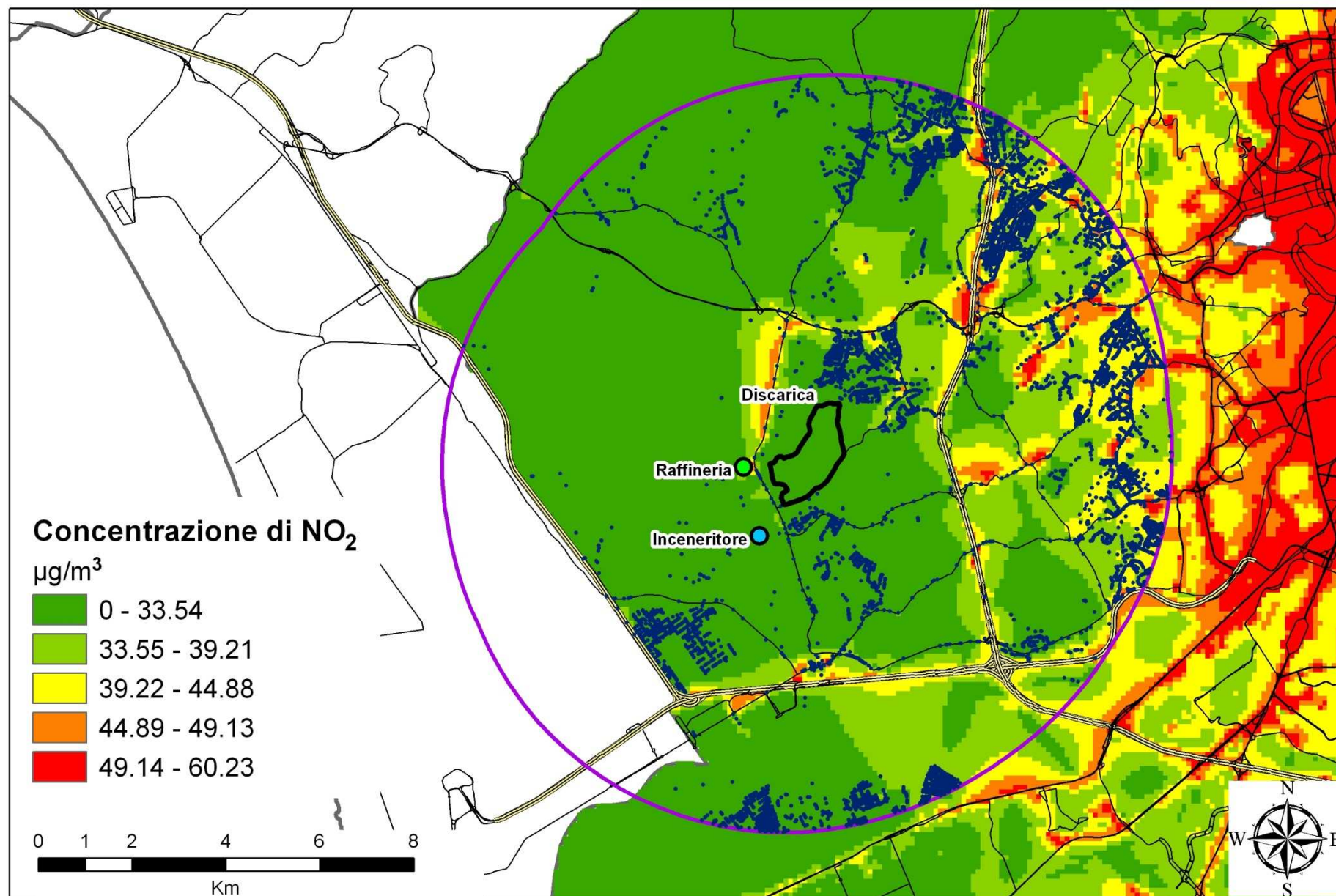


b

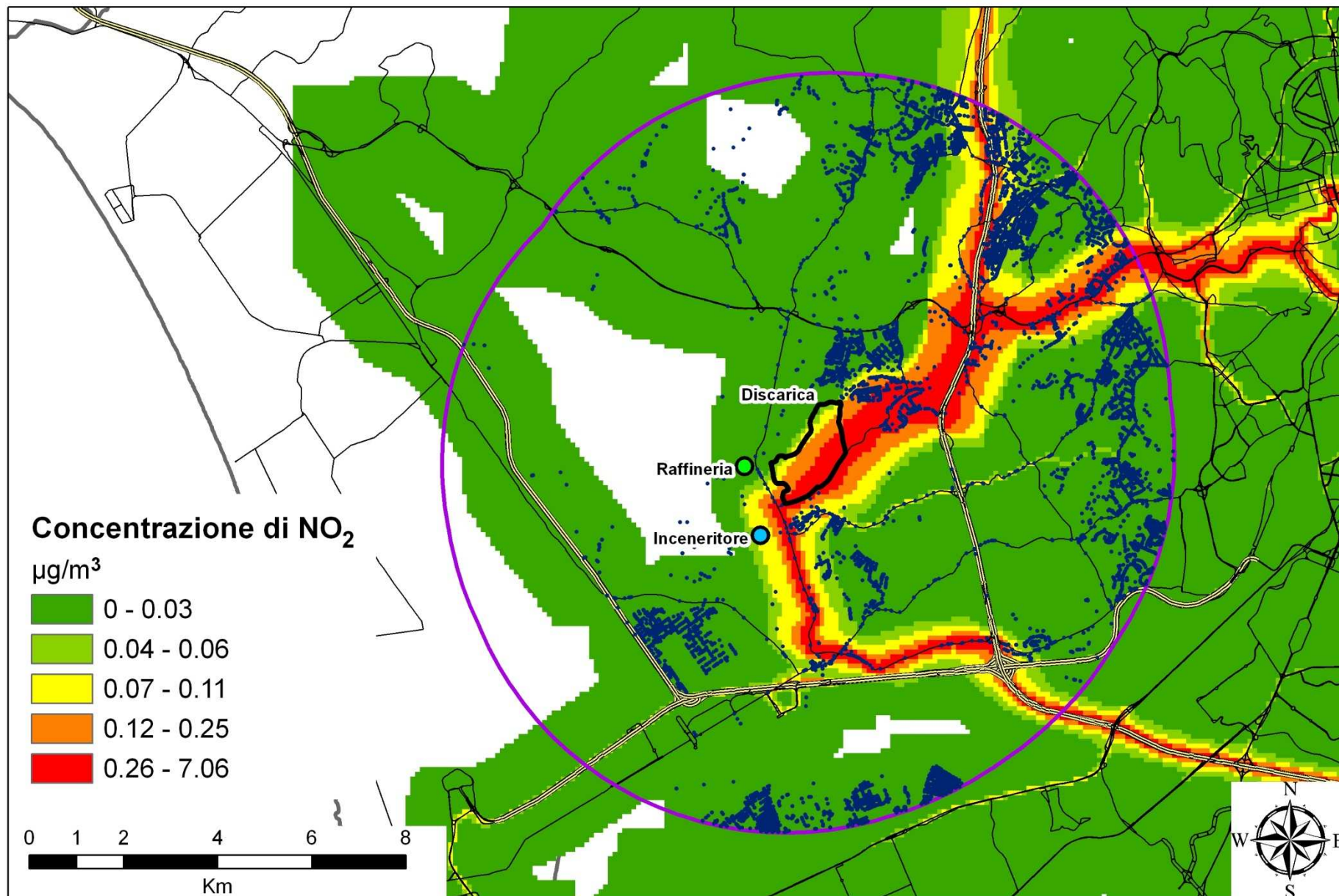




C

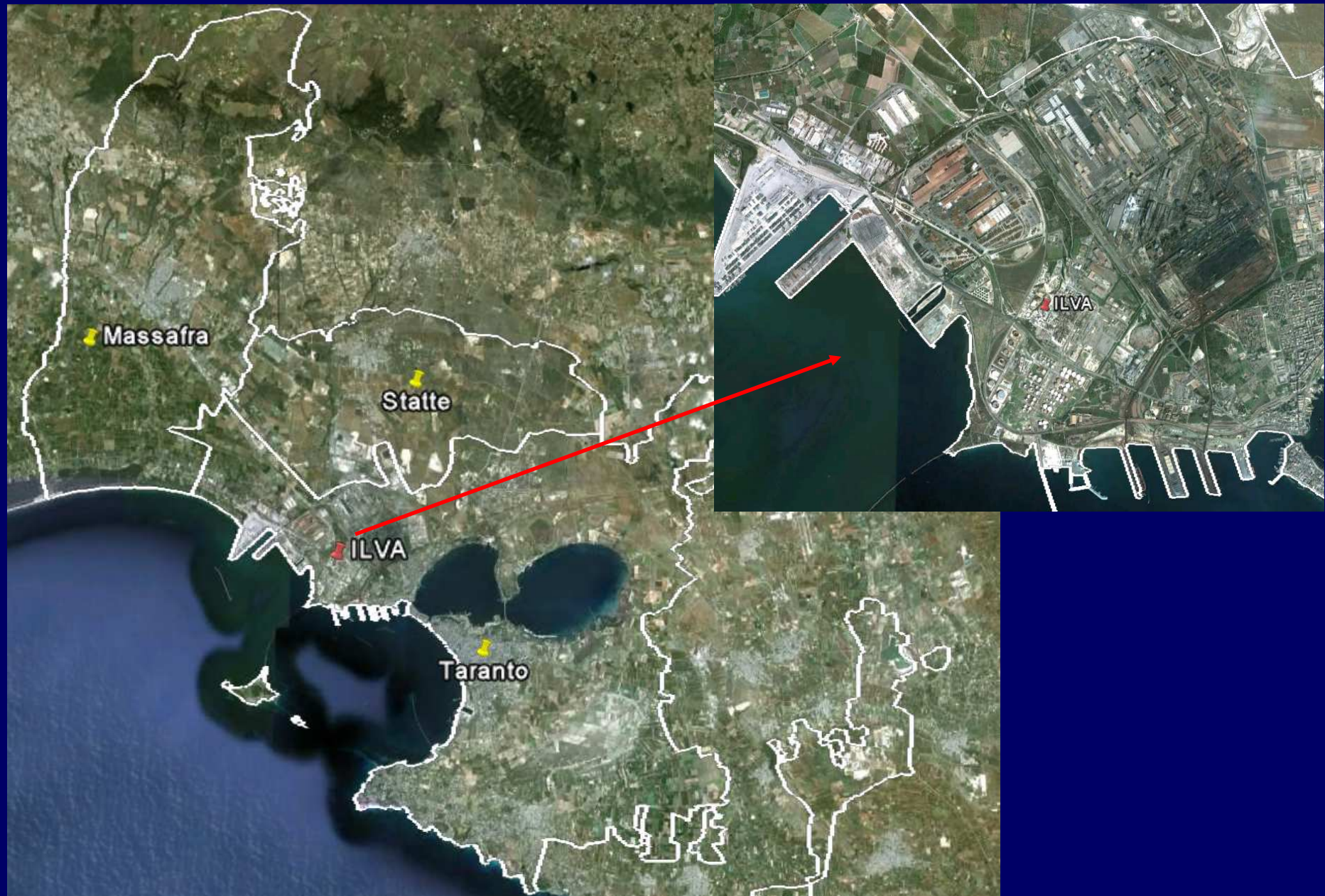


d





# Area in studio: Taranto





Available online at [www.sciencedirect.com](http://www.sciencedirect.com)



Atmospheric Environment 41 (2007) 6432–6444

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**ATMOSPHERIC  
ENVIRONMENT**

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[www.elsevier.com/locate/atmosenv](http://www.elsevier.com/locate/atmosenv)

# Application of a Lagrangian particle model to assess the impact of harbour, industrial and urban activities on air quality in the Taranto area, Italy

Claudio Gariazzo<sup>a,\*</sup>, Vincenzo Papaleo<sup>a</sup>, Armando Pelliccioni<sup>a</sup>,  
Giuseppe Calori<sup>b</sup>, Paola Radice<sup>b</sup>, Gianni Tinarelli<sup>b</sup>

<sup>a</sup>*Italian Institute for Occupational Safety and Health (ISPESL), Research Centre, Via Fontana Candida 1,  
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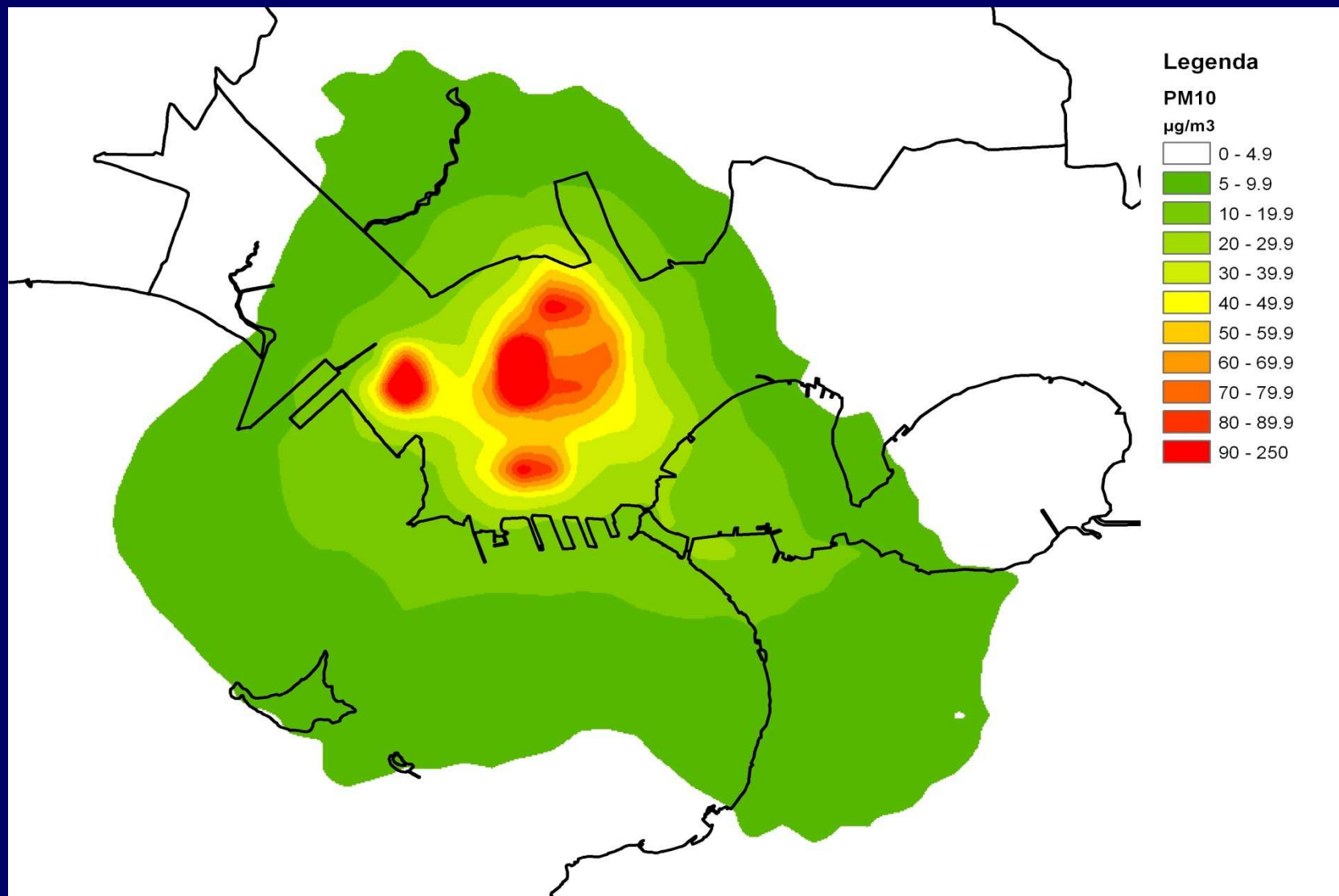
# Effetti a lungo termine: Inquinamento industriale

Modelli di dispersione di PM10: anno 2004, separatamente estate e inverno, mappe di dispersione di PM10 generati da industria

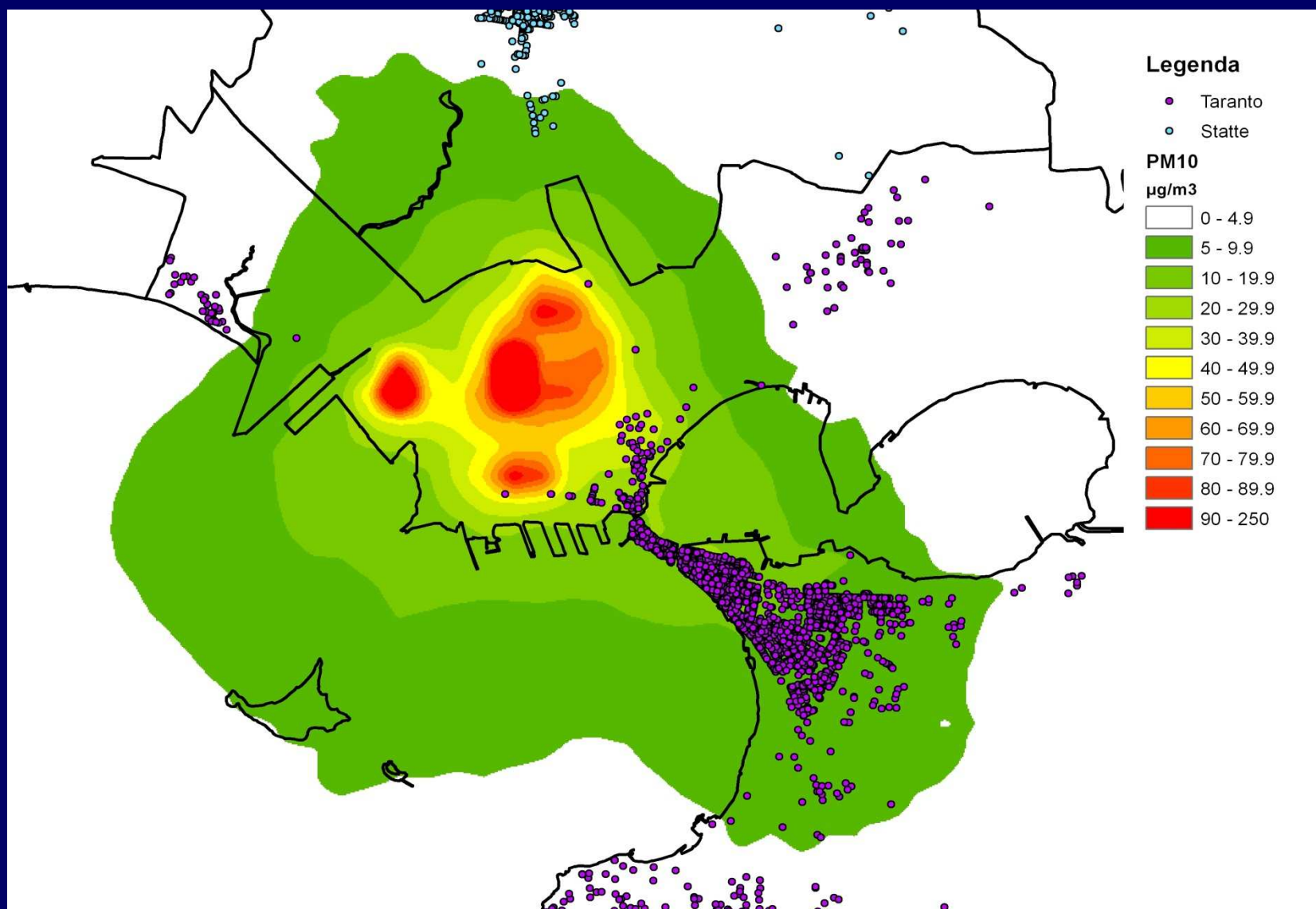


Media dei valori invernale ed estivo, ed attribuzione a livello **individuale** sulla base della residenza al 1 gennaio 1998 (o prima residenza successiva)

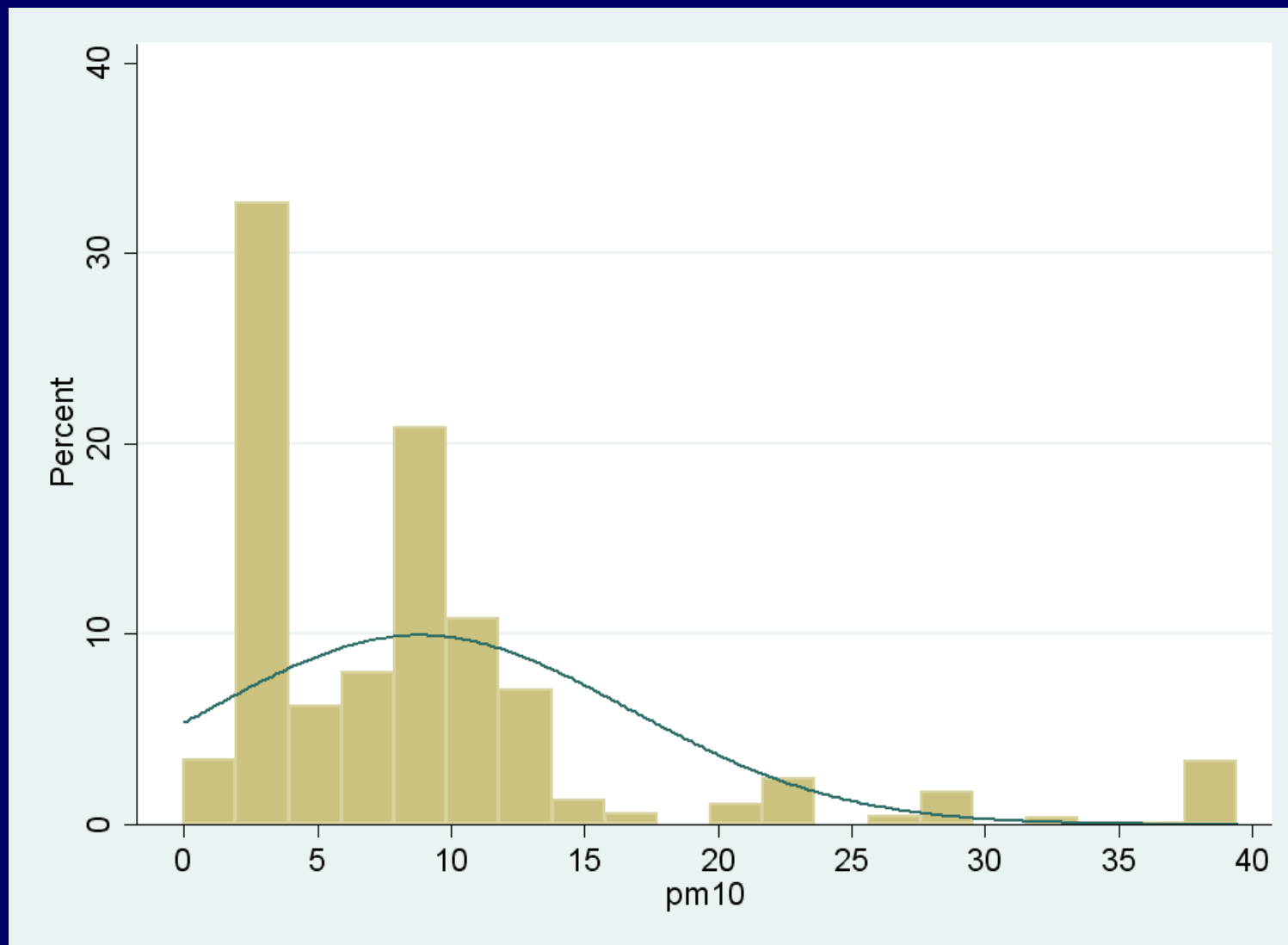
# • Simulazione della concentrazione di $PM_{10}$ di origine industriale



# • Simulazione della concentrazione di $PM_{10}$ di origine industriale



- **Distribuzione di frequenza della esposizione a  $PM_{10}$  di origine industriale**



# Land use regression models (LUR)

Si predice la concentrazione di un dato inquinante in un dato punto sulla base delle caratteristiche del traffico e del territorio circostante

y concentrazione  
misurata nel punto S



Variabile di risposta

x caratteristiche del  
territorio intorno a S



Predittori di y

Date le x dei punti P  
con y sconosciuto



Misura di y in P



# LUR models - applicazioni

- diversi studi condotti in città europee a livello intraurbano
- esempi di variabili indipendenti: volume di traffico della strada, altitudine, tipologia dell'area.
- studi di validazione con l'uso di variabili indipendenti differenti, hanno mostrato la affidabilità del metodo

## LUR models - vantaggi

1. La mappatura empirica basata sul modello di regressione permette di adattare il modello alle differenti aree senza necessità di misurazioni aggiuntive o ricerca di dati
2. Basso costo (NO<sub>2</sub>, dosimetri passivi o Ogawa badge)

## LUR models - limiti

1. Area-specifico: non si può applicare lo stesso modello in aree con caratteristiche del territorio differenti
2. Molto facile da utilizzare per NO<sub>2</sub>, più complesso e costoso con altri inquinanti

# European Study of Cohorts for Air Pollution Effects

– ESCAPE <http://www.escapeproject.eu/>

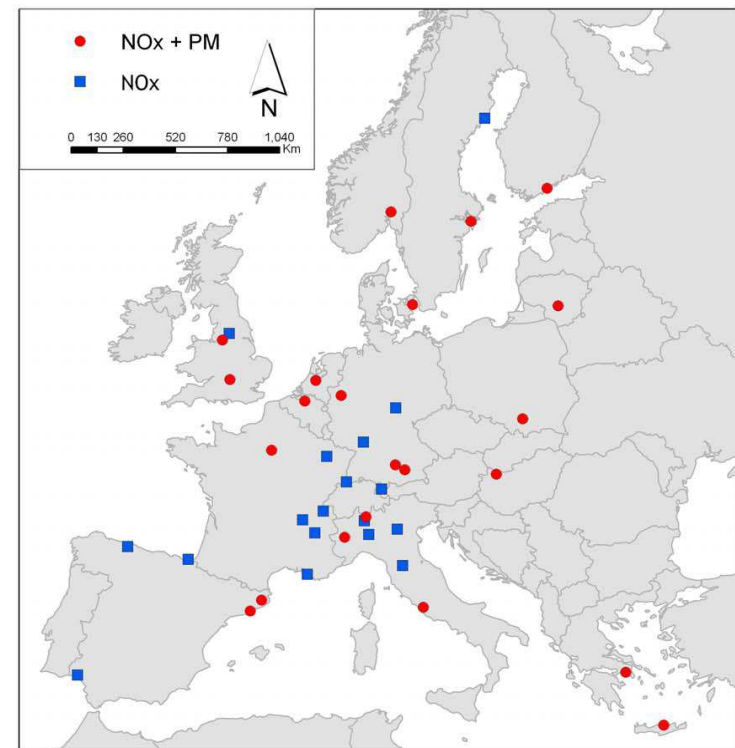
- EU FP7 project, 25 partners, coordinated by Univ Utrecht

- 30 cohorts, total 645,800 subjects followed over several years, ca. 37,000 deaths

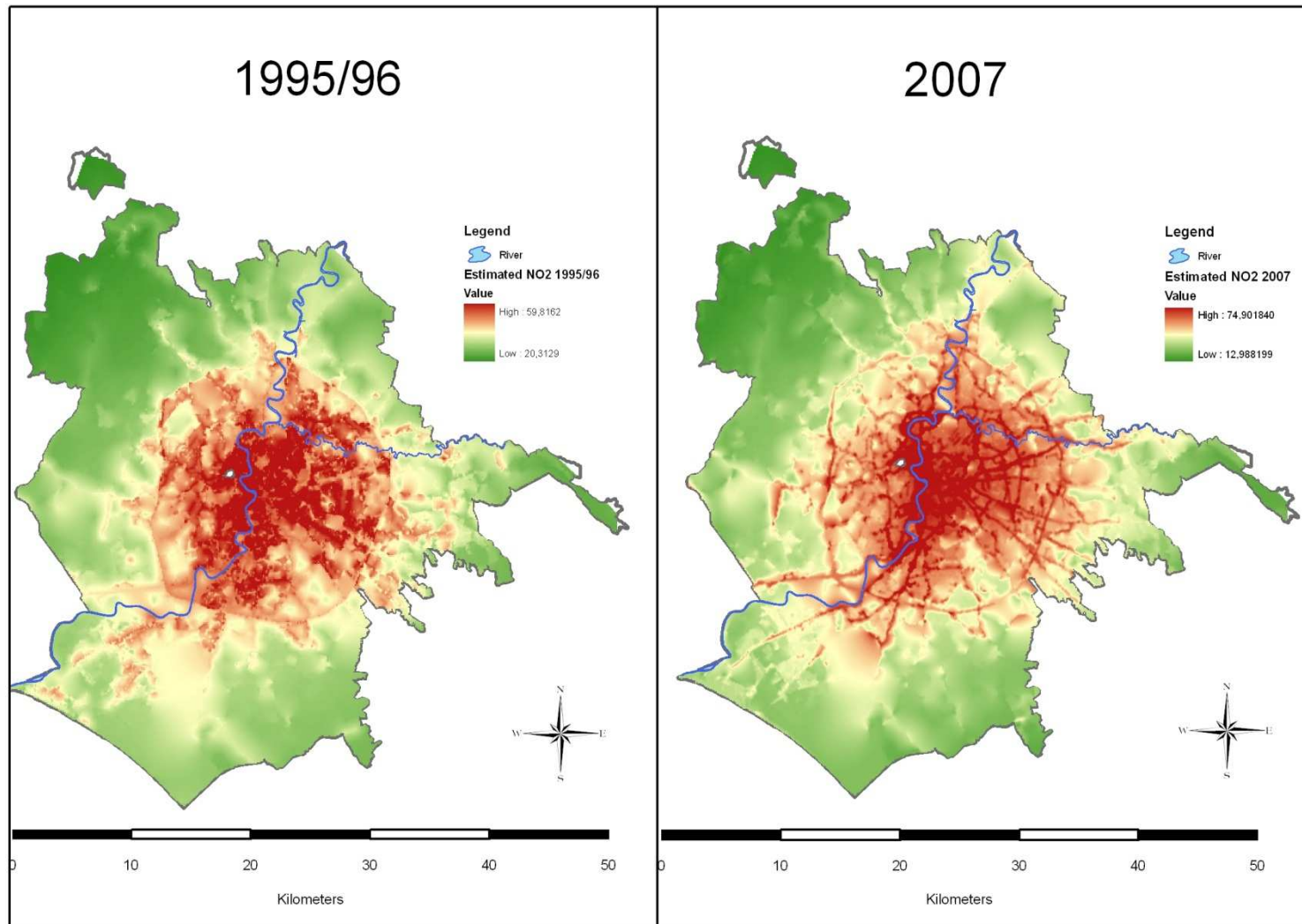
- ESCAPE monitors PM<sub>2.5</sub>, PM<sub>10</sub>, NO<sub>2</sub>, NO<sub>x</sub>, BC, elemental composition of PM (TRANSPHORM)

- Exposure assessment based on land use regression models

- First results expected end-2012



# ROMA: Land use regression NO2







**DIEP** / Lazio

Dipartimento di Epidemiologia del Servizio Sanitario Regionale  
Regione Lazio

# Long-term exposure to $\text{PM}_{2.5}$ and $\text{NO}_2$ and mortality

Cesaroni G, Gariazzo C, Sozzi R, Badaloni C,  
Davoli M, and Forastiere F

Barcelona, 15<sup>th</sup> September 2011



## Background

- The association of natural mortality with exposure to air pollution is well established
- In the last years studies have been published on all-cause mortality, on cardiopulmonary, and on lung cancer mortality  
(Brunekreef et al. 2009; Laden et al. 2006; Miller et al. 2007; Puett et al. 2008, 2009, 2011; Beelen et al. 2008)
- Few European studies on long-term effects of air pollution used PM exposure  
(e.g. Beelen et al. 2008)



## Objectives

To analyze the association of long-term exposure to  $\text{PM}_{2.5}$  and  $\text{NO}_2$  with mortality in a large cohort

- Are women at risk more than men ?
- Are higher socioeconomic groups protected ?

To investigate the role of gender and educational level



## Methods. The Rome Longitudinal Study

A **fixed cohort** enrolled at the 2001 census.

- Selection: subjects aged 45-80 years at the baseline who had not changed their address in the previous five years (n=684,204)
- Data on age, gender, education, occupation, place of birth, and area-based socioeconomic position at baseline
- All subjects were followed till December 31, 2009.
- Cox regression models

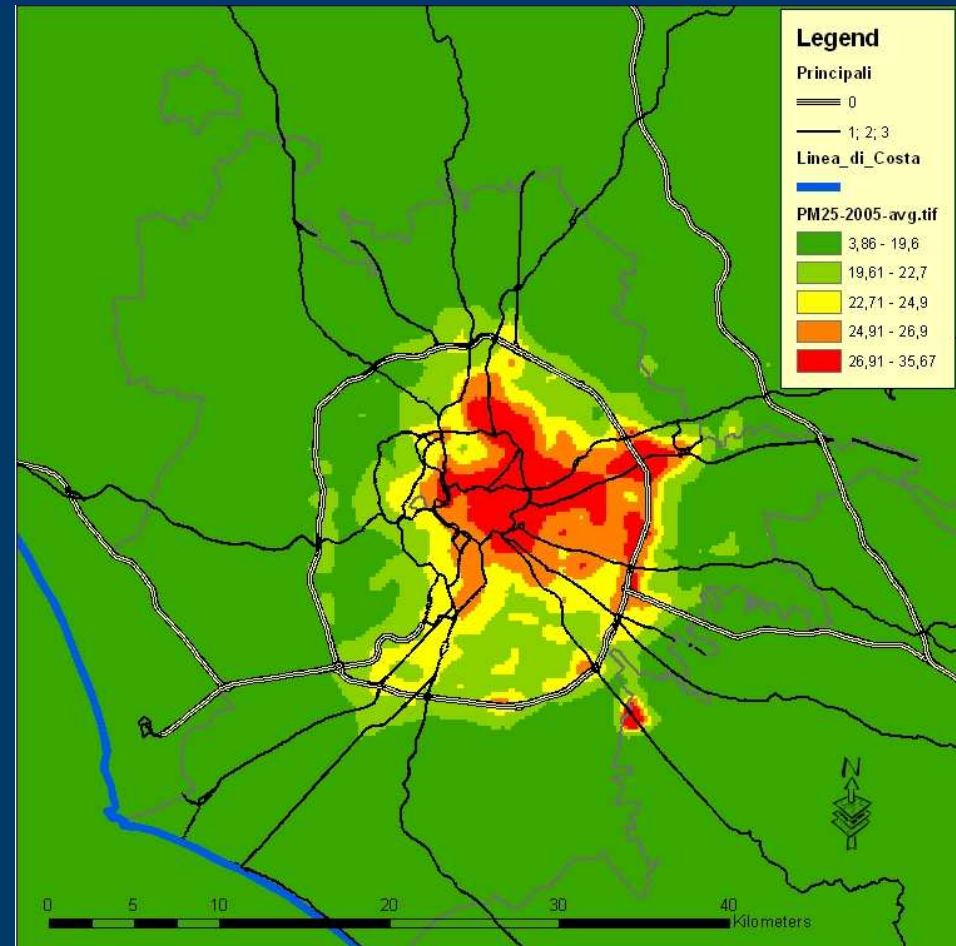


## Methods. $PM_{2.5}$ at residence: dispersion model

- $PM_{2.5}$  Eulerian dispersion model (1km grid)

(Flexible Air quality Regional Model, FARM)

- Regional Environmental Agency, National Research Council, Italian Workers' Compensation Authority
- 2005 emissions inventory
- meteo model RAMS

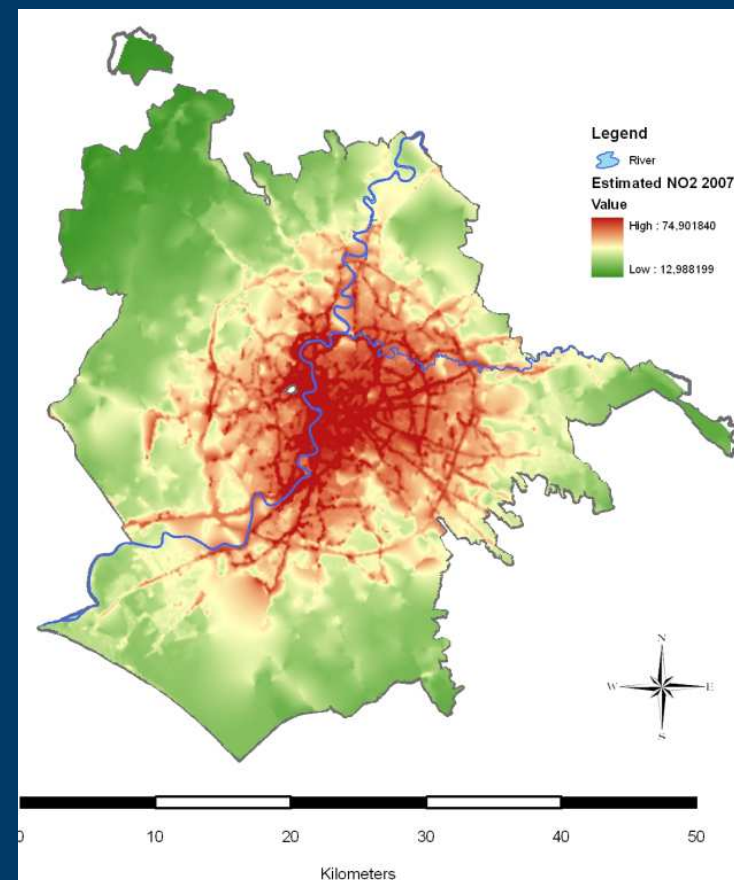






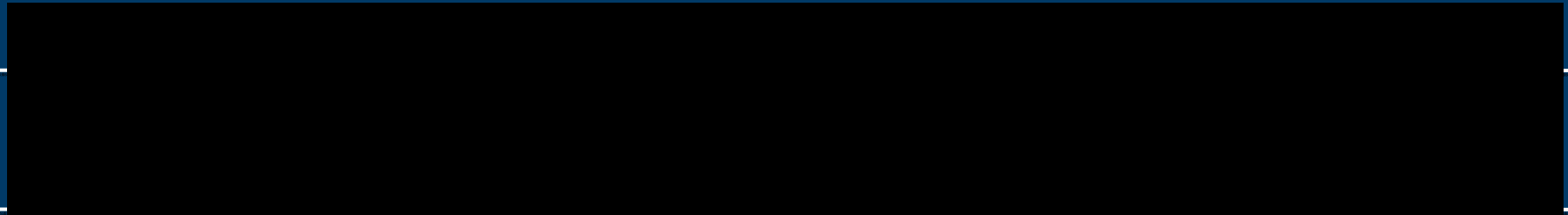
## Methods **NO<sub>2</sub> at residence: LUR model**

- NO<sub>2</sub> was measured at 67 schools during a cross sectional study on children conducted in 1994/1995
- 53 UB sites, 11 TS sites, and 3 RB sites.
- Three Palm diffusion tubes measured outdoor air pollution in each location simultaneously over three one-week periods in June 1995, November 1995, and March 1996.
- Variables: Distance from the city centre, inverse population density of the census block, traffic density in the 150m buffer around the site, distance from the closest road with more than 10,000 vehicles daily, circular traffic zone, altitude, and geographical coordinates
- (Rosenlund 2007)





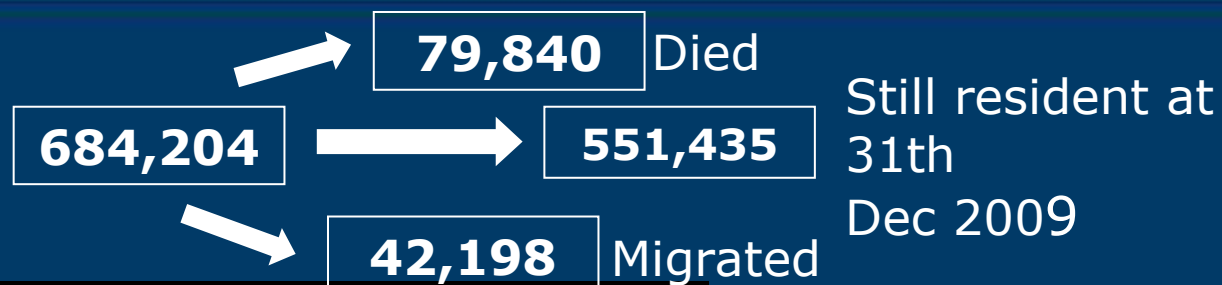
## Results The exposure of the population ( $\mu\text{g}/\text{m}^3$ )



$$\text{Corr}(\text{NO}_2, \text{PM}_{2.5}) = 0.70$$

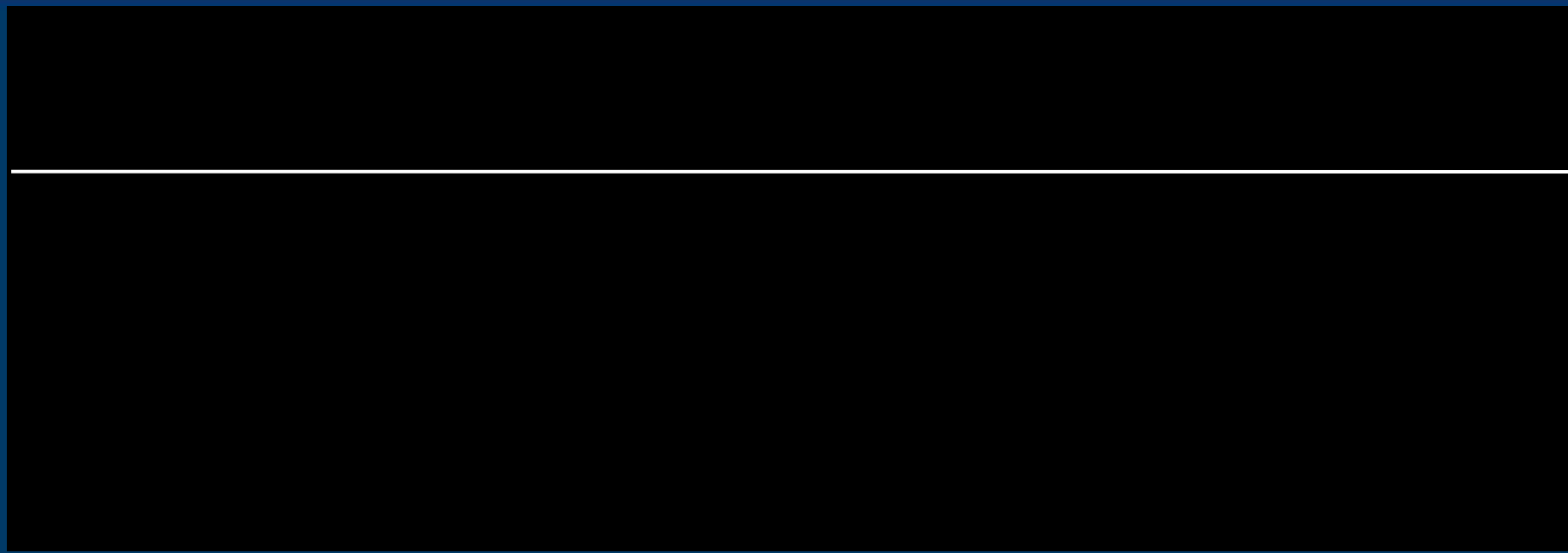


## Results Characteristics of the study population and exposure at residence ( $\mu\text{g}/\text{m}^3$ )



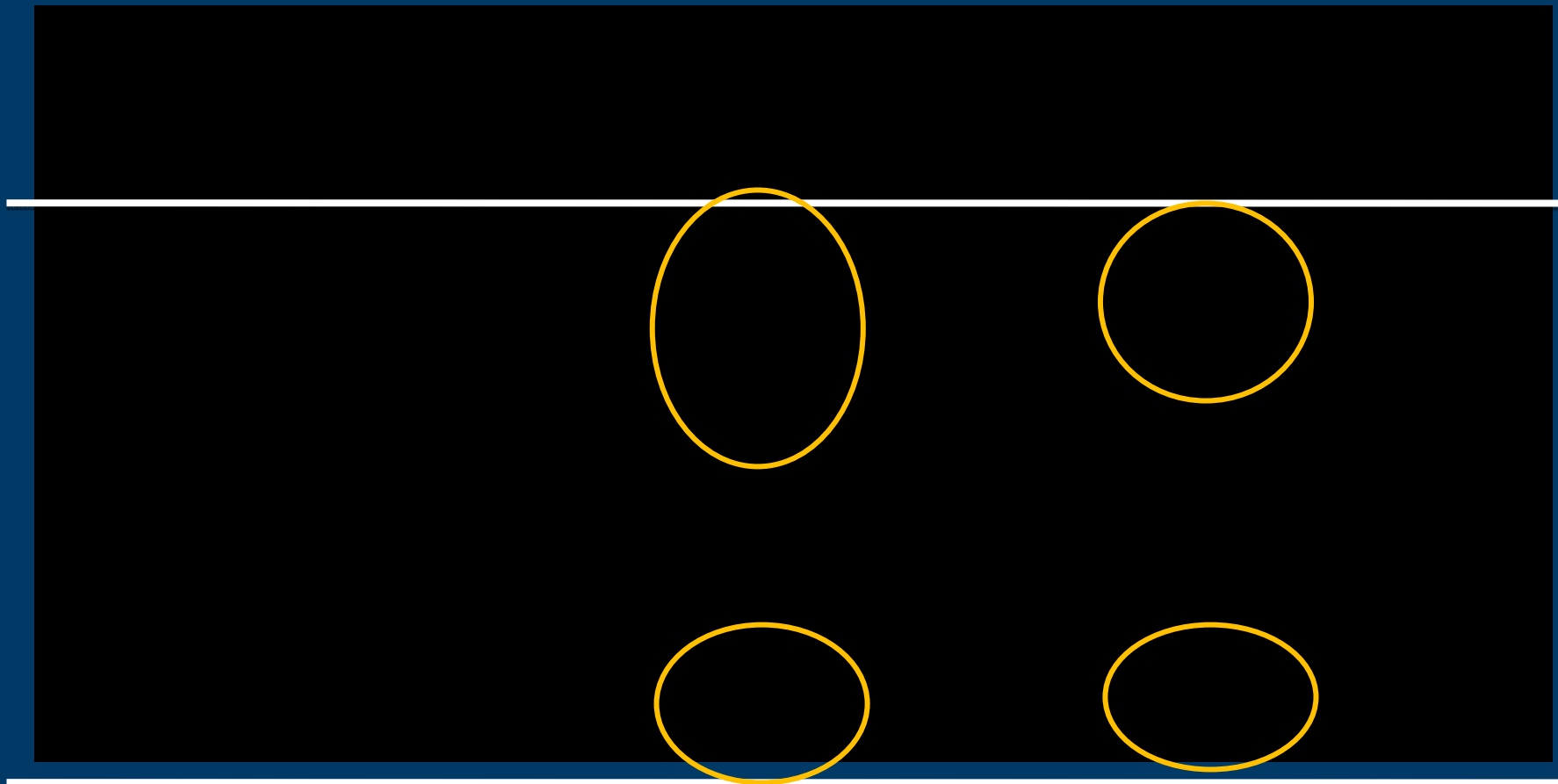


## Results Number of deaths and crude mortality rates





## Results Natural and cause-specific mortality

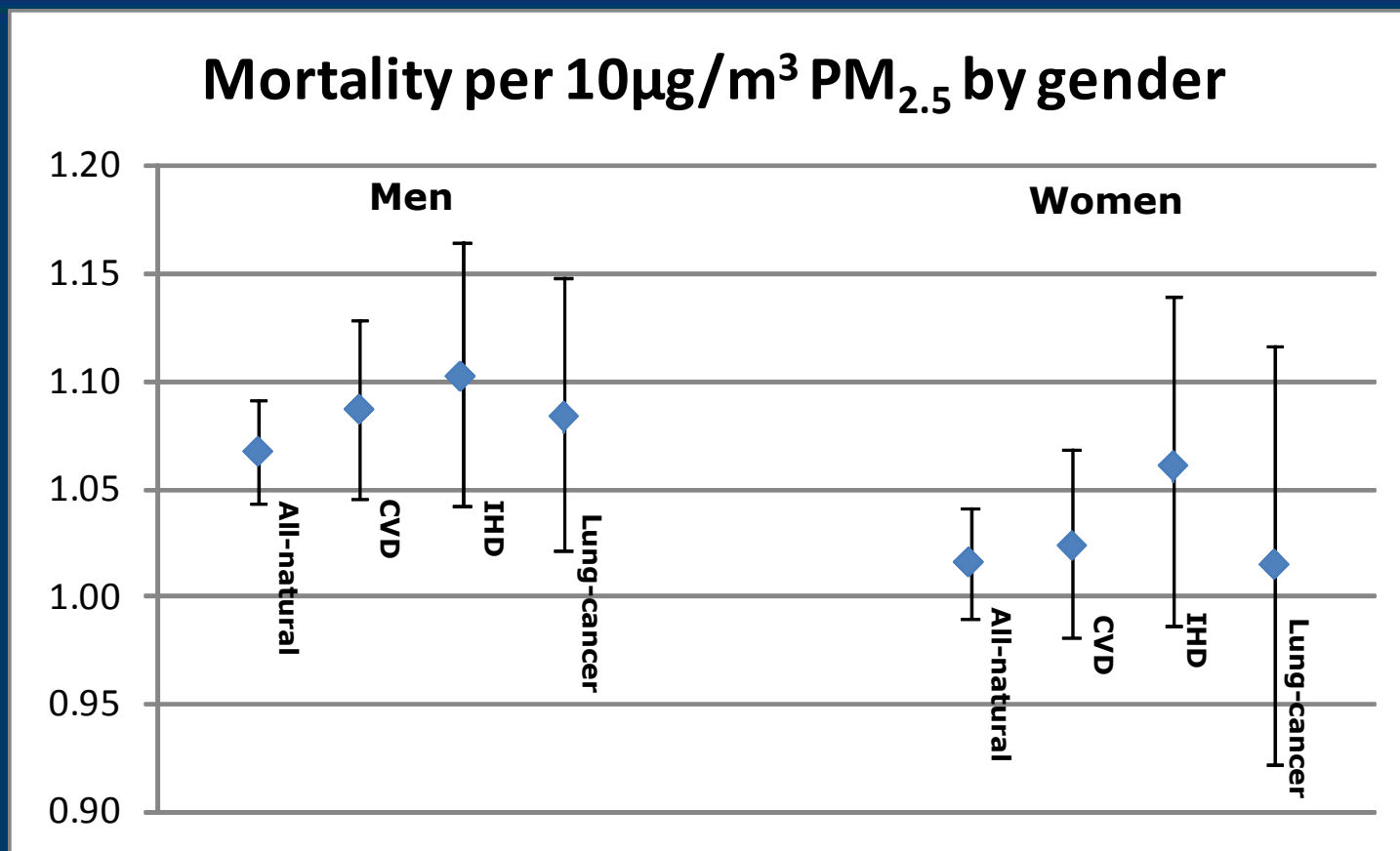


HR Hazard Ratios adjusted for age, sex, marital status, place of birth, education, occupation, and area-based socioeconomic position





## Results Mortality by gender (HRs, 95%CI)



p for interaction sex\*10 $\mu$ g/m<sup>3</sup>PM<sub>2.5</sub> natural mortality: 0.032

HR Hazard Ratios adjusted for age, marital status, place of birth, education, occupation, and area-based socioeconomic position



## Results Natural mortality for $10\mu\text{g}/\text{m}^3$ $\text{PM}_{2.5}$





## Conclusions

This is one of the largest European urban cohort study on  $\text{PM}_{2.5}$  and  $\text{NO}_2$

The results indicate that long-term exposures to  $\text{PM}_{2.5}$ , and  $\text{NO}_2$  at residence are associated with mortality in Rome

For the two pollutants the results are similar

The effect estimates are very similar to what has been suggested in studies from the US

# Conclusioni

- Sono stati evidenziati effetti importanti dell'inquinamento atmosferico
- La valutazione della esposizione umana ha assunto una rilevanza particolare
- Lo sviluppo delle metodologie dei modelli di dispersione e del land use regression models utile per la valutazione degli effetti sanitari e della efficacia delle politiche.

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