BRIDGING GAP IN AIR POLLUTION HEALTH RISK ASSESSMENT: INTEGRATING EARTH OBSERVATION, MOBILITY DATA AND SPATIAL ANALYSIS FOR AIR POLLUTION HEALTH RISK ANALYSES

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8.1M

[Air pollution accounted for 8.1 million deaths globally in 2021, becoming the second leading risk factor for death, including for children under 5 years]

Comprehensive new report details health impacts of air pollution, which has moved ahead of tobacco and poor diet as a risk fact…

LAST UPDATED
June 19, 2024

Health Effect Institute
–
State of Global Air Report / 2024

STATE OF GLOBAL AIR /2024

2nd
largest risk factor of deaths in 2021

Countries in South Asia and Africa face the highest burden of disease.

Global Risk Factors for Death

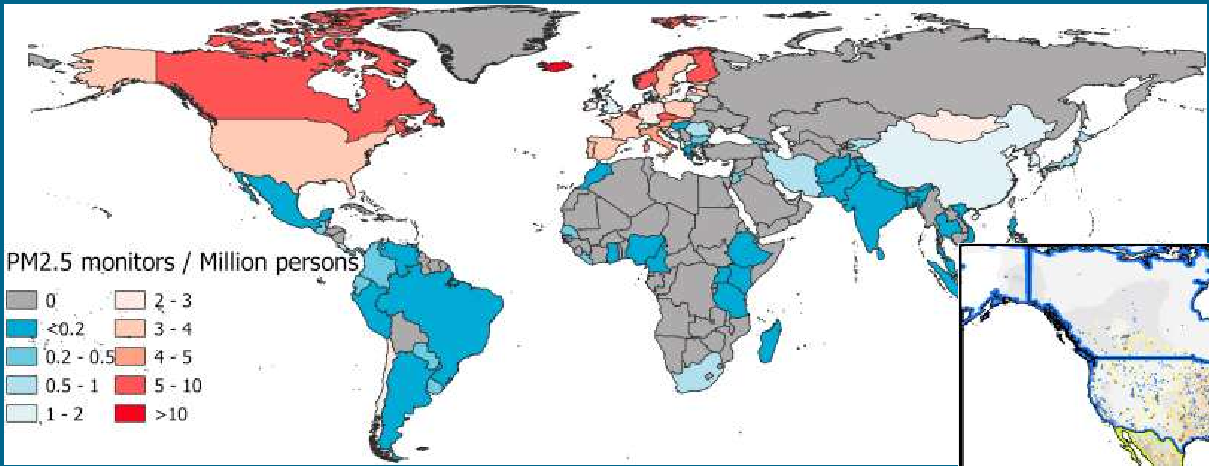
1. High blood pressure
2. Air pollution
3. Tobacco
4. Diet
5. High fasting plasma glucose

1 in 5 infant deaths in Europe and Central Asia linked to air pollution - UNICEF

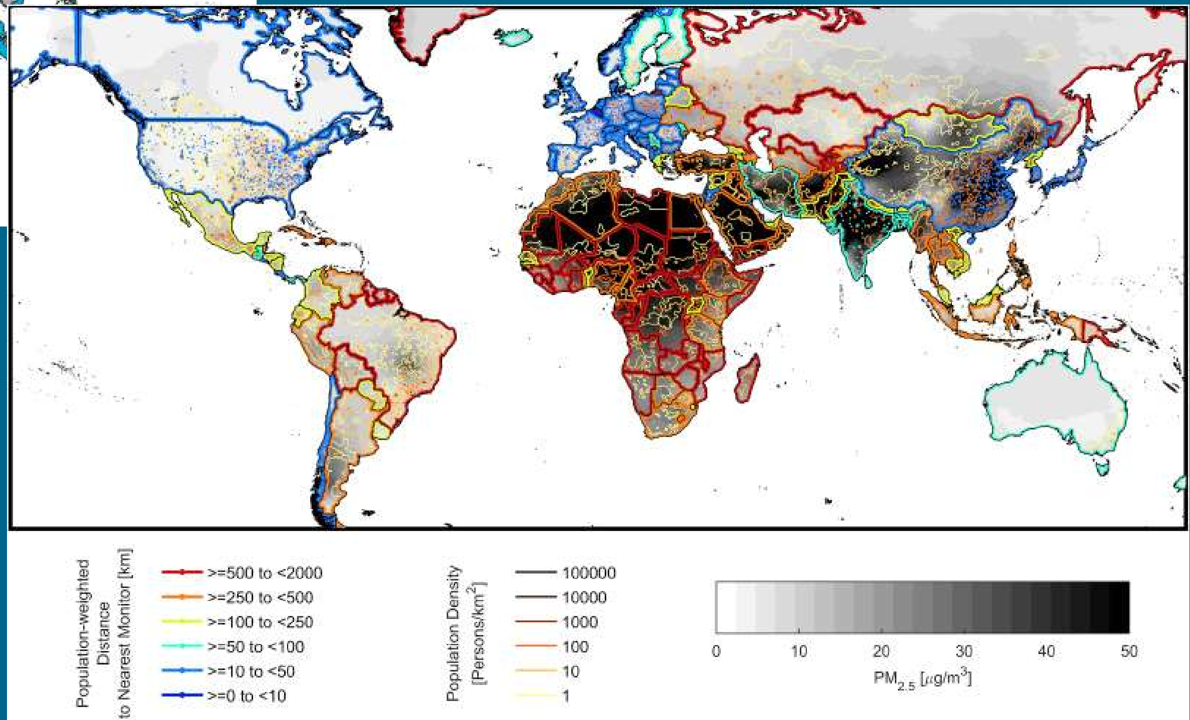
New UNICEF policy brief outlines latest data and policy recommendations to improve air quality and curb air pollution-related deaths and poor health among children

06 September 2024

Exposure assessment and ground based monitoring



Martin et al., 2019
https://doi.org/10.1016/j.aeaoa.2019.100040



- High time resolution
- Poor spatial resolution
- Not uniform distribution

(Long-Term) Exposure Assessment - Challenges

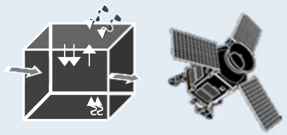
1. **Pollution** concentration **diurnal variability**
2. **Population mobility**
3. **Limited data** in remote/less urbanized areas
4. **Spatial resolution** of pollution dataset

"Ecological Fallacy"

Health risk assessment from air pollution

Risk = Hazard x Vulnerability x Exposure

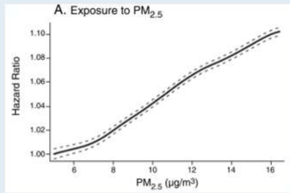
Air quality Maps



Hazard

- Satellite
- Models
- In-situ

Dose-response functions



Vulnerability

- Medical literature

World Settlement Footprint & Mobility matrixes

Exposure

- Demography
- Settlement
- Mobility

How does population mobility affect health risk from air pollution?

Gilardi *et al.*
International Journal of Health Geographics (2023) 22:11
https://doi.org/10.1186/s12942-023-00333-8

International Journal of Health Geographics

RESEARCH **Open Access**

Long-term exposure and health risk assessment from air pollution: impact of regional scale mobility

Lorenza Gilardi[1*], Mattia Marconcini[2], Annekatrin Metz-Marconcini[2], Thomas Esch[2] and Thilo Erbertseder[1]

Abstract

Background The negative effect of air pollution on human health is widely reported in recent literature. It typically involves urbanized areas where the population is concentrated and where most primary air pollutants are produced. A comprehensive health risk assessment is therefore of strategic importance for health authorities.

Methods In this study we propose a methodology to perform an indirect and retrospective health risk assessment of all-cause mortality associated with long-term exposure to particulate matter less than 2.5 microns ($PM_{2.5}$), nitrogen dioxide (NO_2) and ozone (O_3) in a typical Monday to Friday working week. A combination of satellite-based settlement data, model-based air pollution data, land use, demographics and regional scale mobility, allowed to examine the effect of population mobility and pollutants daily variations on the health risk. A Health Risk Increase (HRI) metric was derived on the basis of three components: hazard, exposure and vulnerability, utilizing the relative risk values from the World Health Organization. An additional metric, the Health Burden (HB) was formulated, which accounts for the total number of people exposed to a certain risk level.

Results The effect of regional mobility patterns on the HRI metric was assessed, resulting in an increased HRI associated with all three stressors when considering a dynamic population compared to a static one. The effect of diurnal variation of pollutants was only observed for NO_2 and O_3. For both, the HRI metric resulted in significantly higher values during night. Concerning the HB parameter, we identified the commuting flows of the population as the main driver in the resulting metric.

Conclusions This indirect exposure assessment methodology provides tools to support policy makers and health authorities in planning intervention and mitigation measures. The study was carried out in Lombardy, Italy, one of the most polluted regions in Europe, but the incorporation of satellite data makes our approach valuable for studying global health.

Keywords Exposure assessment, Air pollutants, Satellite-based data, Dynamic population, Diurnal variability, Settlement mask

DOI:10.1186/s12942-023-00333-8

The Influence of Commuting on Population Exposure to Air Pollution: Toward Global Application With a Proxy on the Degree of Urbanization

Lorenza Gilardi, Thilo Erbertseder, Frank Baier, Heiko Paeth, Tobias Ullmann, and Hannes Taubenböck

***Abstract*—Urban populations are significantly affected by air pollution, which poses a major threat to public health. However, standardized and public mobility data, essential for an exposure assessment, are frequently unavailable. Earth observation-derived and model datasets can support large-scale health studies, especially in remote areas with limited data availability. This study investigates the use of a globally derivable variable from remote sensing data to estimate the static versus dynamic population exposure difference. A health risk assessment using a higher and a lower resolution air pollution data was performed. This was achieved by examining air pollution concentrations in two European regions, Lombardy, in Italy, and Germany, incorporating commuting datasets. Accordingly, a retrospective long-term exposure assessment to particulate matter less than 2.5 microns ($PM_{2.5}$), nitrogen dioxide (NO_2), and ozone (O_3) was performed from 2013 to 2022. The study evaluates the difference between the resident and the dynamic population exposed to concentrations exceeding the new limits set by the World Health Organization (WHO). The relation between pollutant concentration and the Fraction of Settlement Area (FSA), a proxy of urbanization levels, derived from the global World Settlement Footprint dataset was explored. Two pollution datasets were used: with European, and global coverage. The analysis decouples daytime and nighttime hours. For each region and pollutant specific FSA thresholds were identified, that maximize the population exposure gap. Our findings highlight the impact of air pollution on population health, revealing widespread exposure exceeding WHO limits, particularly for $PM_{2.5}$, and emphasizing the importance of considering diurnal exposure variations in health risk assessments.**

***Index Terms*—Air pollution, remote sensing, risk analysis, urban areas.**

I. Introduction

THE most recent number of premature deaths in the European Union attributable to air pollution exposure is approximately three hundred thousand per year [1]. According to the estimation given by the World Health Organization (WHO), this number increases to about 4.2 Million on a global level [2]. The exposure to air pollution particularly affects the urban population, whose share in 2022 reached 57% of the global population and 75% in Europe [3]. Moreover, beyond the urban-rural difference in exposure, the air pollution burden is also not equally distributed worldwide. The WHO estimates that 89% of the premature deaths occur in countries classified as low- to middle income, where increasing pollution levels can be observed [2]. Conversely, countries classified as high or upper middle income, although at higher pollution levels, show decreasing air pollution trends over the last decade [4], [5].

Nevertheless, the exposure to an even small concentration of air pollutants poses health risks [6], [7]. In the new Air Quality Guidelines (WHO-AQG) released in 2021, the WHO further decreased the threshold of the maximum air pollutants concentrations considered acceptable in the short- and long-term exposure ranges [8]. For this reason, an accurate estimation of the population exposure to air pollution becomes even more crucial. This information is essential for improving epidemiological studies, deepening our understanding of exposome-response mechanisms and, most importantly, for the accurate planning of active and passive countermeasures to minimize detrimental effects on the population.

In the body of literature on environment and health, exposure indicators are often provided in the form of air pollution and air quality maps. The population, if considered at all, is usually statically linked to the place of residence [9], [10]. Several studies have demonstrated that neglecting the mobility patterns of the population and the pollutants' diurnal variability, leads to errors in the population exposure estimation [11], [12]. In addition, the selected pollution data source significantly affects the exposure assessment due to its specific spatial and temporal coverage and its defined resolutions. For studies conducted at a large scale, a tradeoff in one of these aspects is, due to the current data situation, unavoidable. Especially in remote areas and in the global south, this phenomenon is even more prominent. Datasets with global coverage, such as satellite remote sensing data due to

Manuscript received 12 March 2024; revised 5 June 2024; accepted 18 June 2024. Date of publication 1 July 2024; date of current version 24 July 2024. This work was supported by the frame of the German Aerospace Center (DLR)-through the project "Environmental Stressors and Health Costs". *(Corresponding author: Lorenza Gilardi.)*

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This article has supplementary downloadable material available at https://doi.org/10.1109/JSTARS.2024.3420155, provided by the authors.

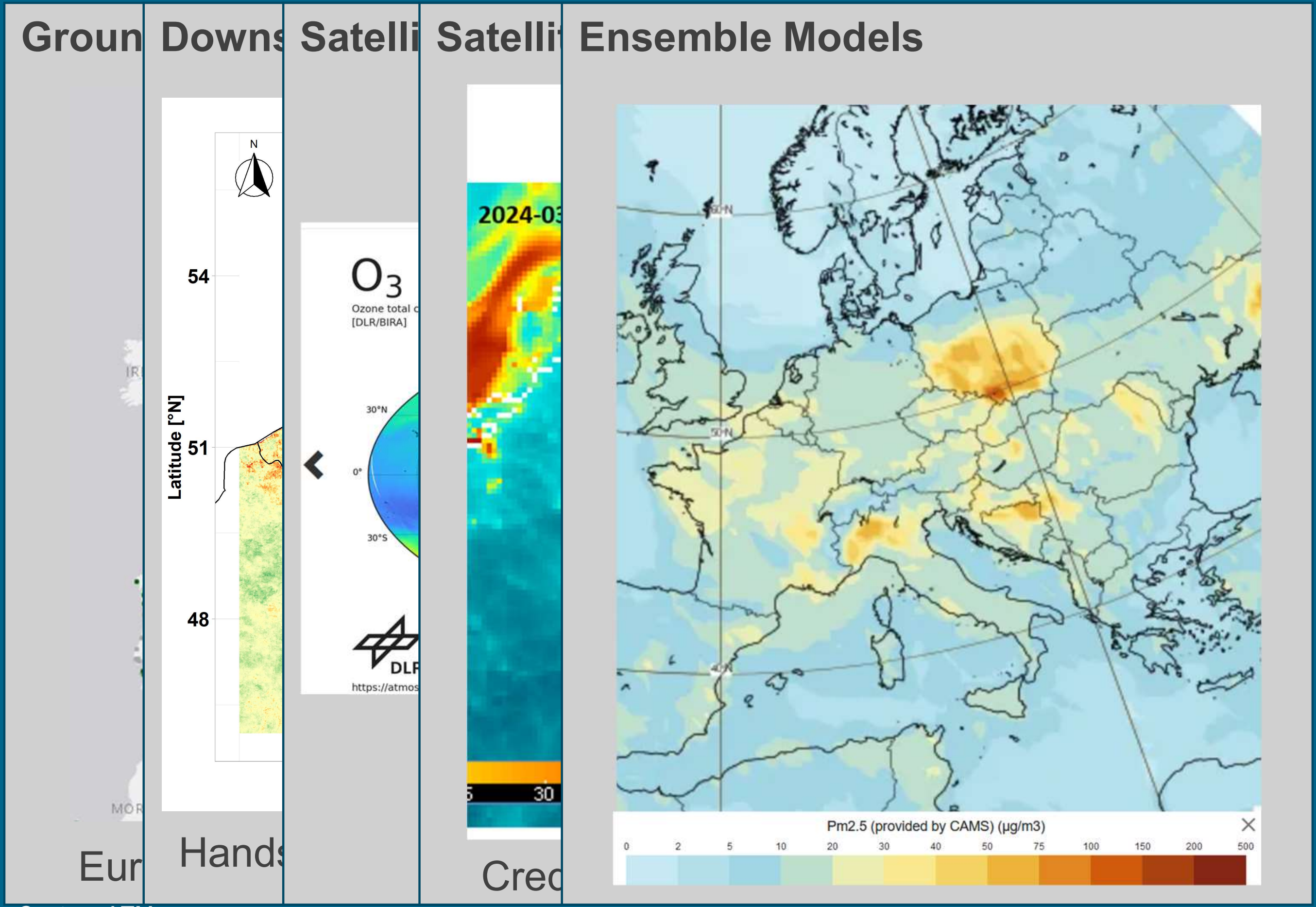
Digital Object Identifier 10.1109/JSTARS.2024.3420155

DOI:10.1109/JSTARS.2024.3420155

DLR

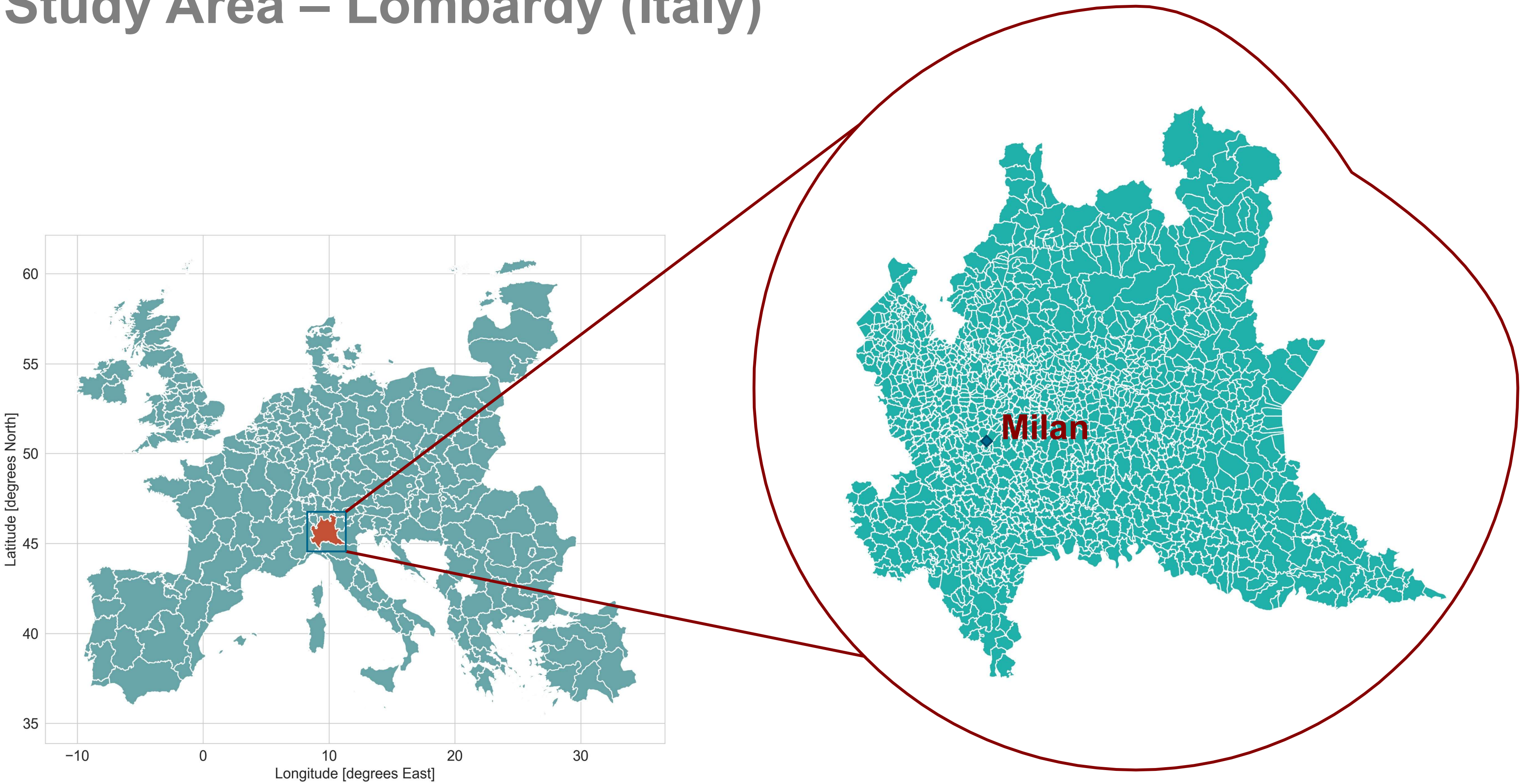
Long-term exposure and health risk assessment from air pollution: impact of regional scale mobility

Available data:



Lorenza Gilardi, German Remote Sensing Data Center - ATM seminar, 20.02.2025

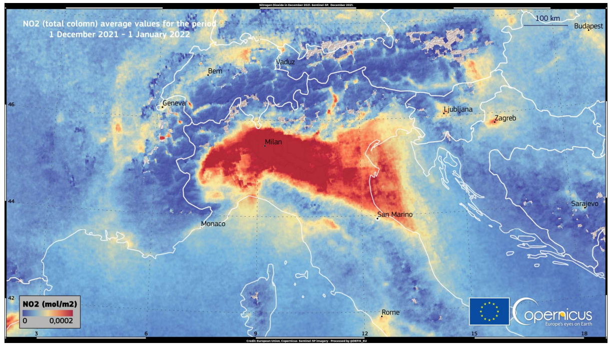
Study Area – Lombardy (Italy)



Study Area – Lombardy (Italy)

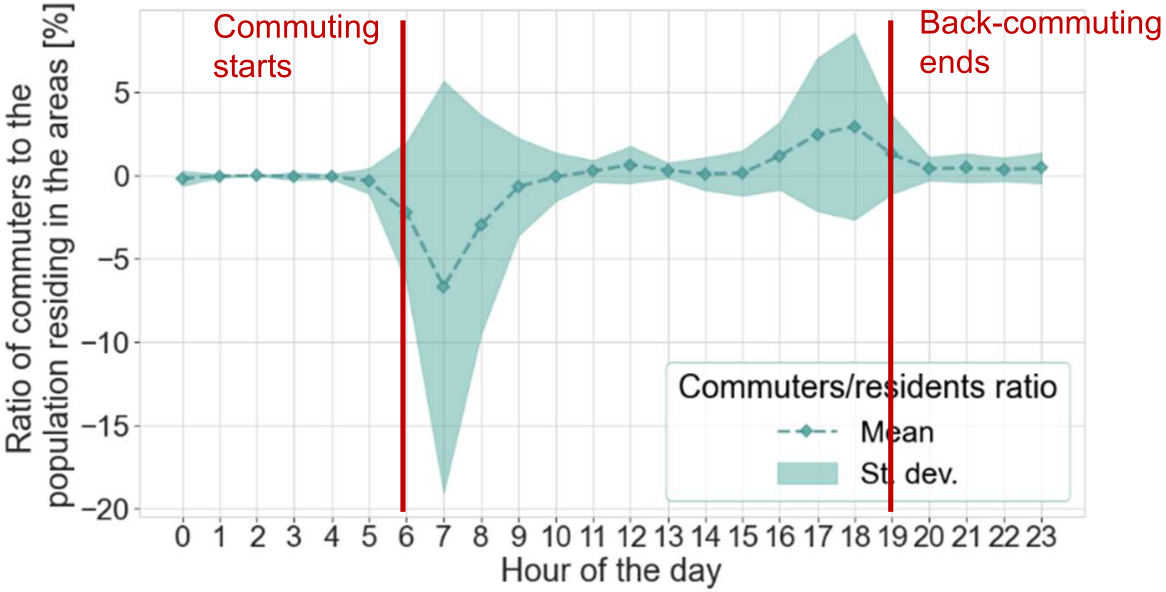
- One of the **most polluted areas in Europe**
    - Densely populated (~10M 1/5th of Italian population)
    - High industrialization and urbanization
    - Peculiar geomorphology limits mountain ranges limit the diffusion in the boundary layer
- **Open access mobility dataset** from the Regional Authority

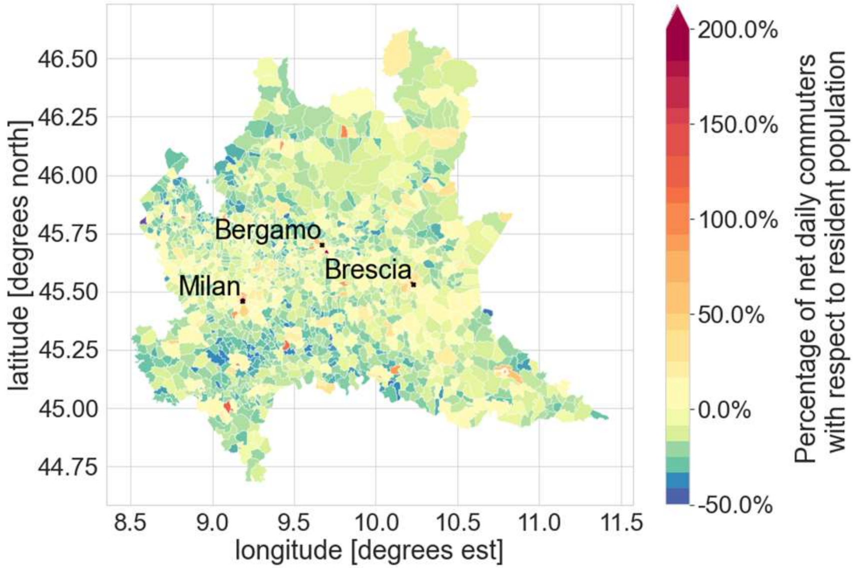
European Union, Copernicus Sentinel-3 imagery, 03/10/2023- veil of haze stretching from Piedmont to the Adriatic Sea



European Union, Copernicus Copernicus Sentinel-5P imagery, average value of tropospheric nitrogen dioxide (NO2) measured between 1 and 31 December 2021 in the Po Valley (Northern Italy).

Methodology: Identification of mobility patterns

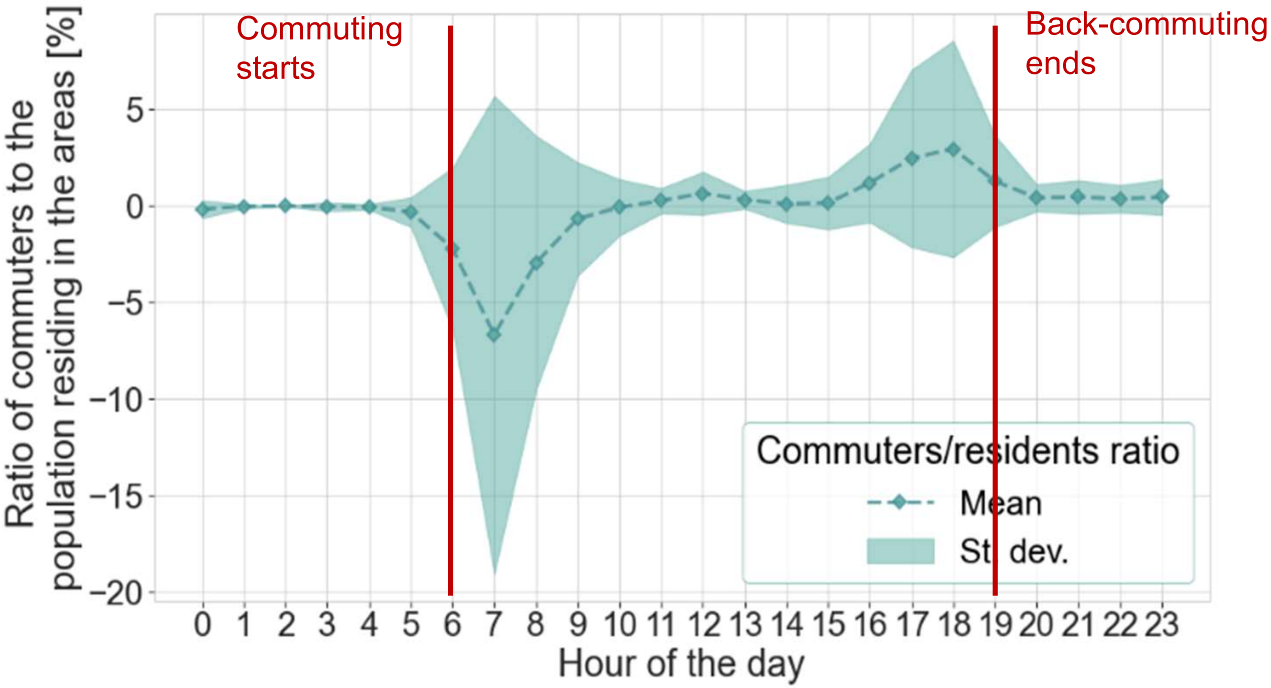




→ Definition of a **daytime** and a **night time hours**

→ Definition of a **daytime** and a **night time population**

Methodology: Identification of mobility patterns

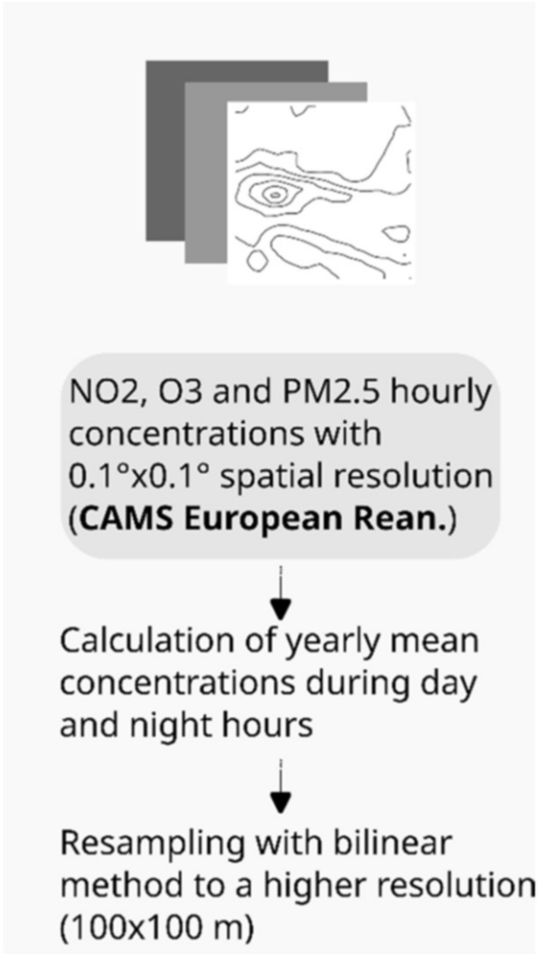


→ Definition of a **daytime** and a **night time hours**
→ Definition of a **daytime** and a **night time population**

Methodology: Calculation of long term statistics for the pollutants PM2.5, NO2 and O3

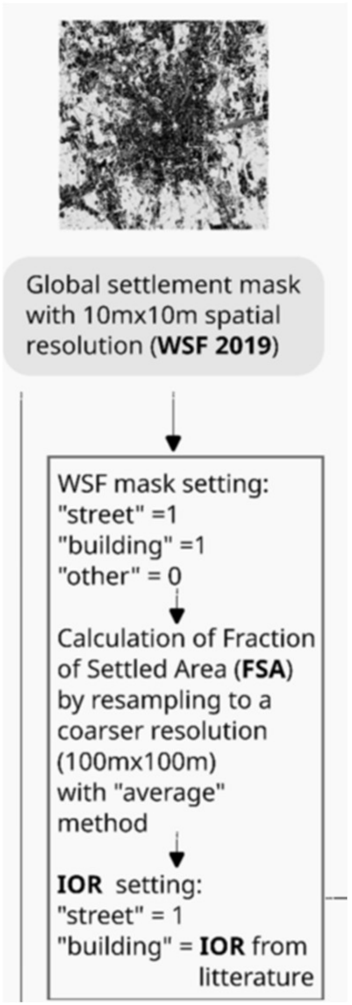
Separately for **day** and **night** hours:

- Multiannual mean for PM2.5
- Multiannual mean for NO2
- Seasonal peak parameter for O3



Methodology: targeting the exposure

- Definition of the **Fraction of Settlement Area** (FSA) from the World Settlement Footprint (Marconcini et al, 2021)
- Masking by **settlement type** (building vs street) and applying the **outdoor/indoor infiltration ratios** (IOR)
- **Redistribution of the population** according to the **land use and daytime** (residential, industrial, commercial)



Introduction to the concept of Relative Risk (RR)

RR

- Measure to estimate the **influence** of a **factor (*i*)** on the exacerbation of a specific **Health Outcome (*HO, i.e. disease*)**
- Derived **from epidemiological studies**
- *RR_i = f (level of exposure, health outcome, age, sex)*

$$RR_i = \frac{Prob.\,of\ disease\ with\ exposure}{Prob.\,of\ disease\ without\ exposure}$$

$> 1 : negative\ effect\ on\ health$

$= 1 : no\ effect\ on\ health$

$< 1 : beneficial\ effect\ on\ health$

- RR_i are provided in literature for several pollutants species and/health outcomes combinations
- RR_i are usually proportional to an increment of 10 $\mu g/m^3$ of the pollutant's concentration

Methodology: definition of two health risk metrics

Health Risk Increase (HRI):

$$HRI = C * \frac{RR - 1}{10} * FSA * IOR$$

Health Burden (HB):

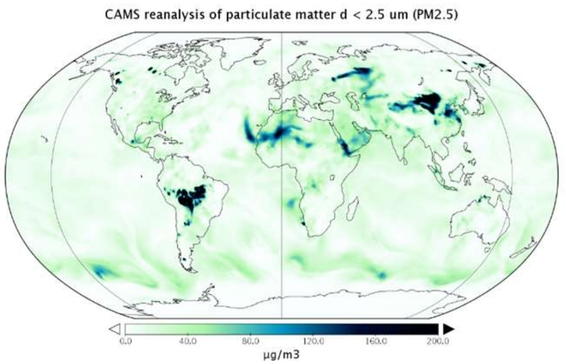
$$HB = HRI * P$$

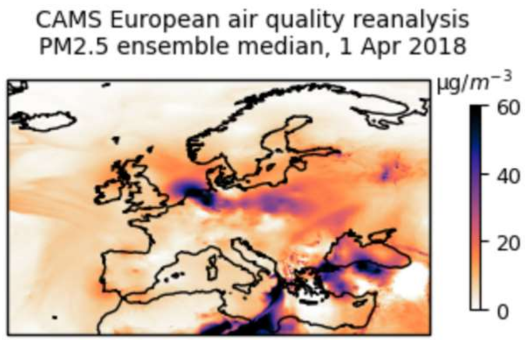
C = pollutant concentration [µg/m3]
RR = Relative Risk of Mortality due to all causes
FSA = Fraction of Settlement Area
IOR = Indoor/Outdoor ratio
P = population [# of inhabitants]

Lorenza Gilardi, German Remote Sensing Data Center - ATM

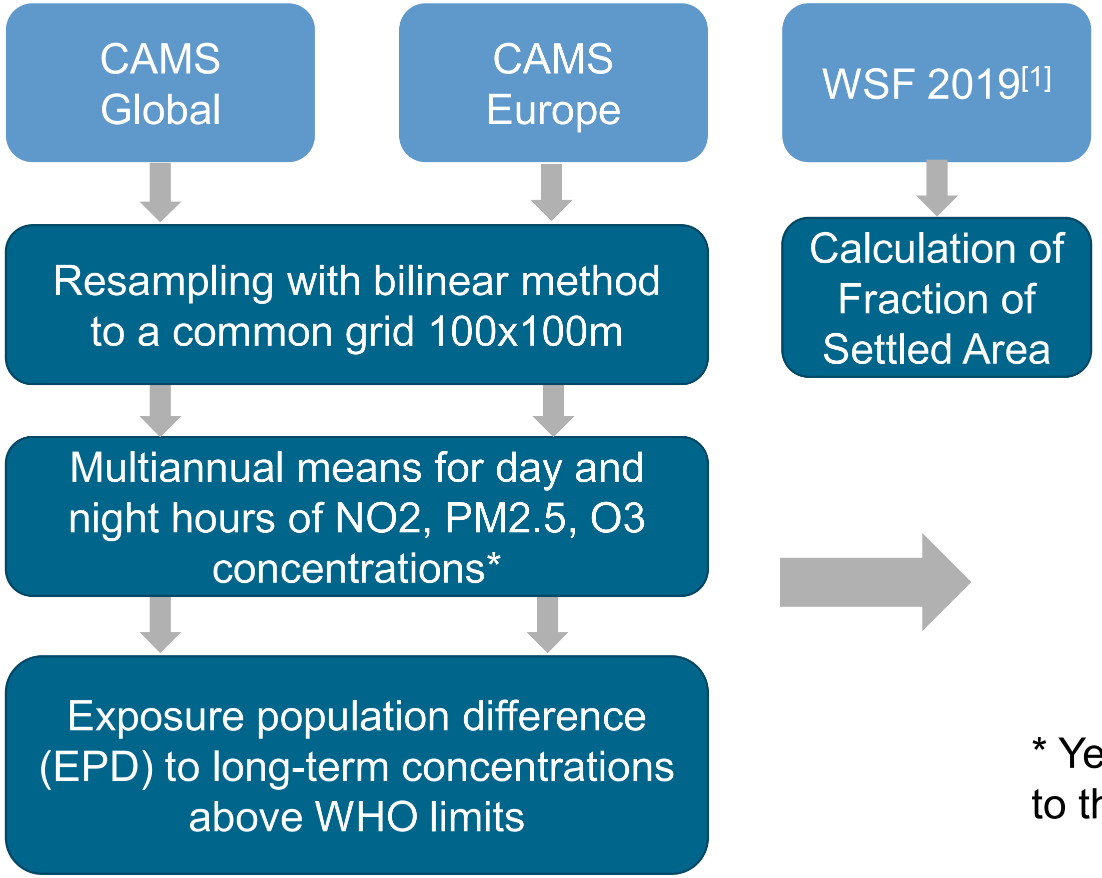
Effect of pollution dataset spatial resolution and global applications

	CAMS Global reanalysis (EAC4)	CAMS European reanalysis
Horizontal coverage	Global	Europe
Temporal resolution	3-hourly	1-hourly
Horizontal resolution	0.75°x0.75°	0.1°x0.1°
Source	ECMWF- Atmosphere Data Store (ADS)	ECMWF- Atmosphere Data Store (ADS)





Effect of pollution dataset spatial resolution and global applications - Methodology

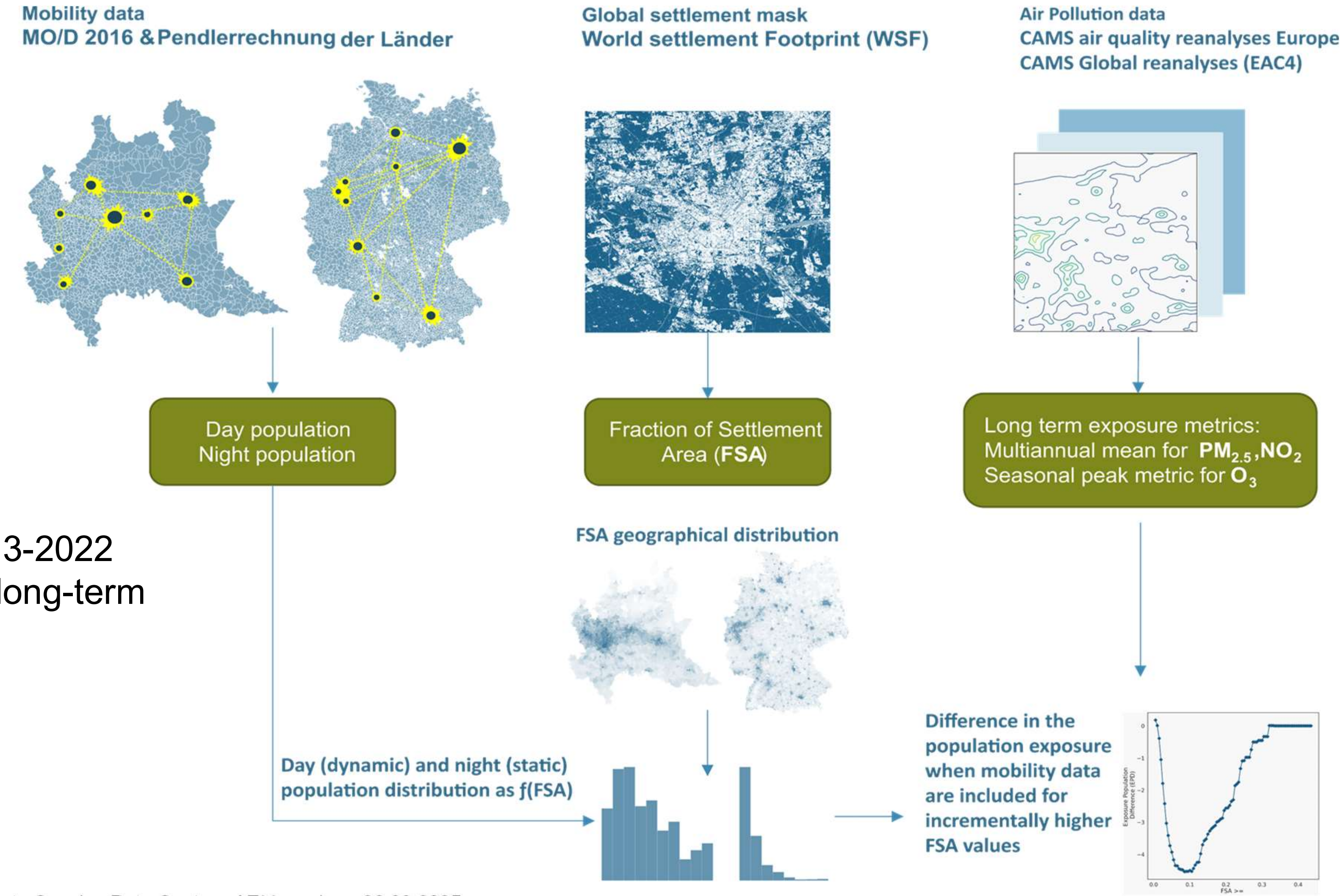


[1] Marconcini, Mattia und Metz-Marconcini, Annekatrin und Esch, Thomas und Gorelick, Noel (2021) *Understanding Current Trends in Global Urbanisation - The World Settlement Footprint Suite.* Austrian Academy of Sciences Press. ISDE12, 6 - 8 July, Salzburg, Austria. doi: 10.1553/giscience2021_01_s33.

$$\boldsymbol{EPD = f}(FSA)$$

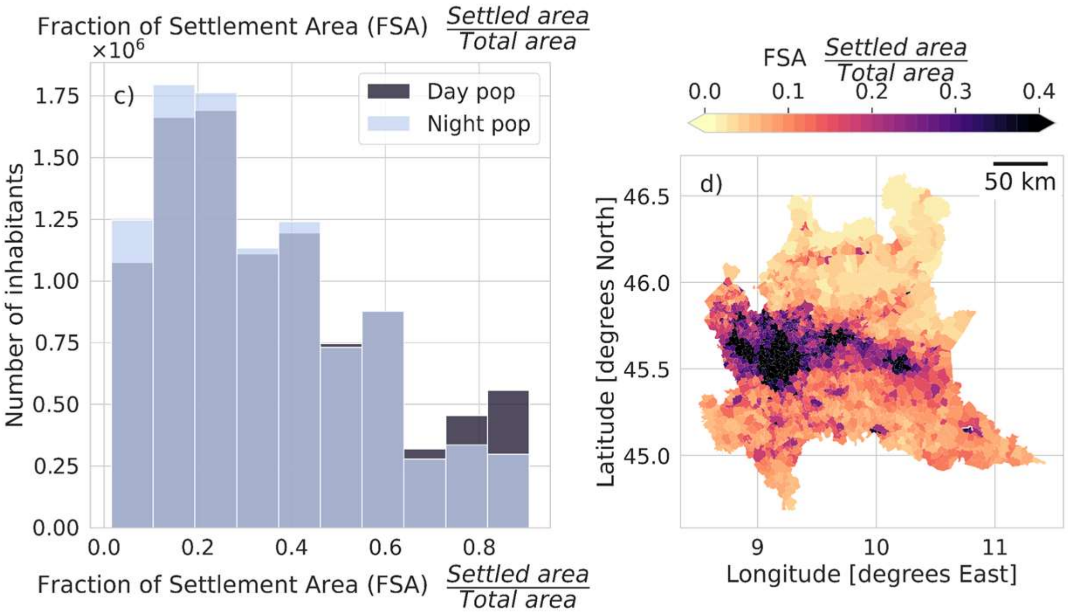
* Yearly aggregates(2013-2022) according to the World Health Organization standards

Outlook



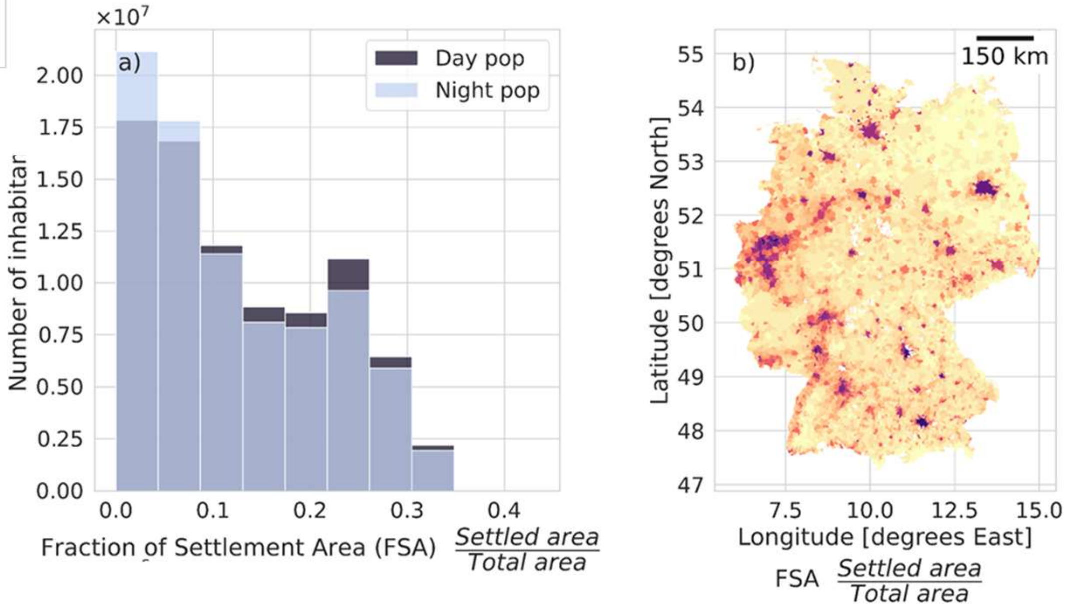
- time frame: 2013-2022
- WHO limits for long-term exposure

Results



10M inhabitants

84M inhabitants



Effect of pollution dataset spatial resolution and global applications

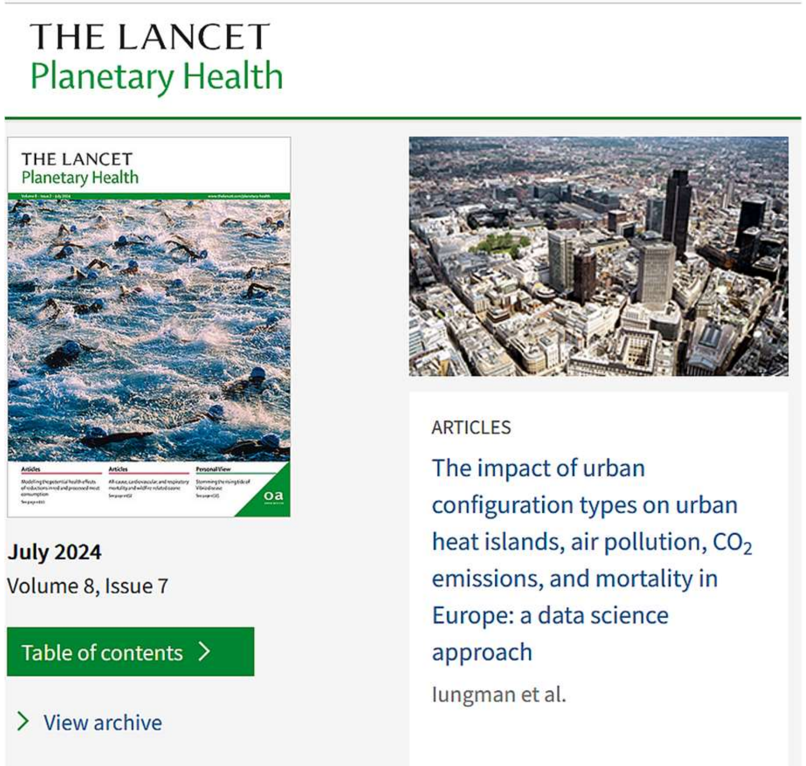
Outcomes:

- **90 million people (the almost totality) exposed to unsafe $PM_{2.5}$ levels:**
  - Nearly the entire population considered (90M) experienced **long-term $PM_{2.5}$ concentrations exceeding WHO limits**.
- **High exposure to multiple pollutants:**
  - The **majority of the population** was exposed to excessive levels of **O_3 and NO_2**, increasing health risks.
- **Exposure variations due to commuting:**
  - Accounting for mobility patterns, **exposure differences range from 100,000 to several million people**, emphasizing the impact of daily movement.
- **Urbanization influences pollution exposure:**
  - Disparities in air pollution exposure are linked to urban density, as measured by the **Fraction of Settlement Area**.
  - However: **no FSA fixed threshold** could be determined
- **Global datasets support exposure assessment:**
  - Satellite-based global air pollution datasets enable **preliminary evaluation of long-term population exposure**, aiding large-scale health risk analyses.

Urban morphology and health risk

How to build healthy and sustainable cities?

→ Systematic analysis of 919 cities in Europe concerning the impact of urban configuration types on urban heat islands, air pollution, CO_2 emissions, and mortality



Iungman, T, Khomenko, S, Pereira Barboza, E, Cirach, M, Gonçalves, K, Petrone, P, Erbertseder, T, Taubenböck, H, Chakraborty, T and M Nieuwenhuijsen: The impact of urban configuration types on urban heat islands, air pollution, CO2 emissions, and mortality in Europe: a data science approach, The Lancet Planetary Health, Vol 8, Issue 7, 2024, https://doi.org/10.1016/S2542-5196(24)00120-7.

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How to build healthy and sustainable cities?

Compact cities have lower carbon emissions, but poorer air quality, less green space and higher mortality rates

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How to build healthy and sustainable cities?

Compact cities:

+ lower carbon emissions
+ better walkability
+ less urban sprawl,

- poorer air quality,
- less green space
- higher mortality rates

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Future work: an environmental justice perspective

NO_2

Remote Sensing of Environment 270 (2022) 112839

Contents lists available at ScienceDirect

Remote Sensing of Environment

journal homepage: www.elsevier.com/locate/rse

Tropospheric NO_2: Explorative analyses of spatial variability and impact factors

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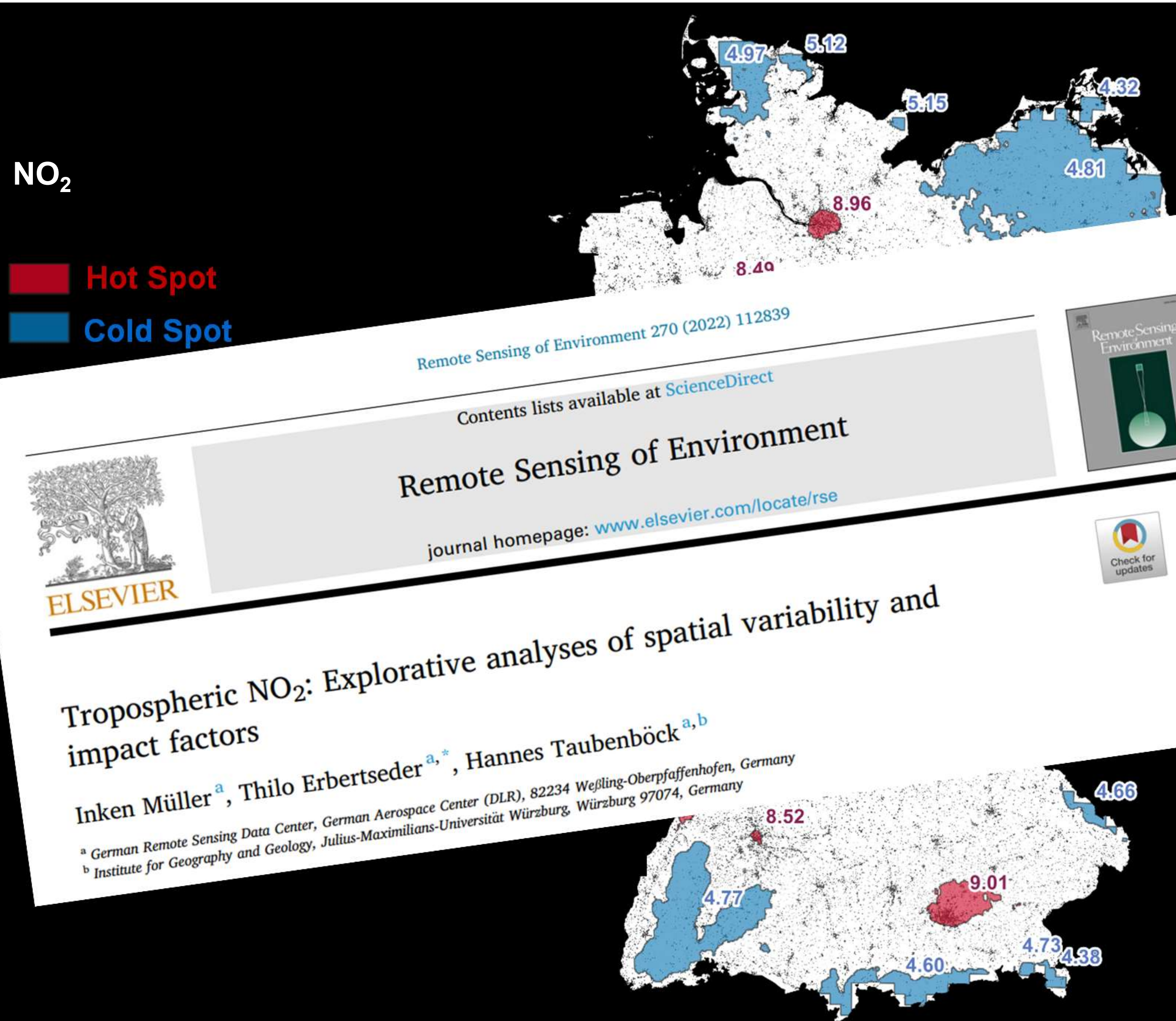

Jährliche troposphärische Säulendichte NO_2 (10^{-5} mol/m^2)

Berlin

Kraftwerk Jänschwalde

Müller et al. 2022

Home

AlpAirEO

SDG3 Good Health and Well-being
SDG9 Industry, Innovation and Infrastructure
SDG11 Sustainable cities and communities
SDG13 Climate action

cloud-based, on-demand service displaying air quality and health metrics for Europe at LAU level.

Contact: Frank.Baier@dlr.de

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