Global Urban Monitoring and Assessment of Environmental Health Risks

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User Needs → Co-Design → Implementation → Sustainability
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Cape Town
WSF population

People per pixel (10x10m)

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First worldwide 3D mapping of the built environment (Esch et al., 2023)
WSF evolution 1985-2015

Processing of entire Landsat archive (~7,000,000 scenes)
Unique precision in the **global analysis of settlement and population growth**

*Sustainable Development Goal 11.3.1*

- High income country
- Upper middle income country
- Lower middle income country
- Low income country

Size of the circles proportional to log(total population)
The Global Human Footprint of Air Pollution

Monitoring of NO₂: Mean 2007 - 2019

MetOp/GOME-2
10:30 local time
up to 5000 overpasses per geolocation

Erbertseder et al., 2015 (updated)
Relative NO$_2$ Trends for Megacities (%/year)

Period covered: 1996 - 2015

Income groups indicated according to world’s economies classification of the World Bank (2022)

NextGEOSS Pilot: Data and Information Fusion on Demand

NextGEOSS: Air Quality in Megacities (1.0) | wps

WSF

Sentinel 5P NO₂

GOME2 TropNO₂ Timeseries Analysis

11/03/16
Observations 8.9
Linear Fit 4.8
Weatherhead Fit 6.72

Resumee:

Atmospheric trace gas trend over built up areas as defined by the Global Urban Footprint (GUF)

Absolute trend (linear W): 0.27
Absolute trend (Weatherhead Model): 0.29

eXposure is provided for 덴스

All results are provided as (10^14 molecules)/per year

Total Health Burden

DLR
Integrated Assessment of Urban Climate and Health Risk

Environmental Stressors/Exposome:
- Noise
- Heat
- Cold
- Pollen
- Radiation
- \(O_2\), \(NO_2\), \(SO_2\), \(PM_{2.5}\), \(PM_{10}\)

Health Endpoints:
- Cardio-Vascular Diseases
- Respiratory Diseases + Influenza + Covid-19
- Skin- and Metabolic Diseases

Age, Activity, Genetic Disposition, Pre-conditions
Health risk assessment from air pollution – impact of mobility

Study region: Lombardy, Italy

Day vs night population

Mobility Patterns

Probability of exposure

Fraction of Settled Area (FSA)

Land use

Infiltration ratios

DAY and NIGHT long term aggregates of NO2, O3 and PM2.5

Pollutant specific Relative Risks of mortality

Long-term DAY and NIGHT Health Risk Increase (HRI)

Health Risk from PM2.5 NO2 and O3 exposure increases when considering a dynamic (commuting) population.

From Global Scale to Street Level: Combing satellite data and atmospheric modelling

Earth Observation
Monitoring
Initialisation
Static Driver
Evaluation
Process Studies

Cascade of Nesting

Polyphemus/DLR MECO(n), EMAC

25 m

22 km

6 km

1 km

Palm-4U

Landshuter Allee, Munich
NO₂-Pollution by Road Traffic in Hamburg

PALM-4U Simulation
Hamburg City Center
15 March 2022, 7:00 to 9:00 a.m.
5 x 5 m spatial resolution

Building and turbulence resolving LES model for entire cities

Nested into the Coupled Chemistry-Climate Model MECO(n)

terrabyte DLR Cooperation with LRZ Supercomputing Center

PALM-4U – LES Urban Climate Model (Cutting-Edge Community Model)

**Urban surfaces**
- Energy balance
- Heat conduction
- Indoor climate & energy demand
- Green elements

**Radiation**
- Radiation budget
- Shading
- Reflections

**Impact**
- Multi-agent system
- Biometeorological analysis

**Chemistry**
- Transport
- Reactions
- Photolysis
- Emissions
- Aerosols

**Vegetation**
- Energy balance
- Momentum sink
- Shading

**Technical solutions**
- Mesoscale nesting
- LES-LES nesting
- RANS mode
- User-friendly GUI

**Soil**
- Roots
- Soil temperature
- Soil moisture

Maronga et al. 2020
PALM-4U Simulations for Entire Cities (Munich)

Coupling of scales:
Urban Canopy Layer (UCL) → Urban Boundary Layer (UBL) → Mesoscale Circulation → Urban Plumes (downwind) that can be observed with TROPOMI and aircraft in-situ (DLR/Cessna)

NO₂, 20 Aug 2020, 12 – 16 (3D-Distribution)
PALM-4U - Hot Spot Landshuter Allee, Munich

Recirculation effects in street canyons
Assessment of Thermal Stress

Air Temperature vs. Thermal Stress (UTCI)

20.-21. August 2020, 48h Mean [°C]
Indoor extremes during a heatwave

Spatial and Temporal Variability of Heat Stress

P1 Verschattung durch Hochhaus (Mercedes)
P2 Innenhof Wohnblockrandbebauung
AQ Luftmessstation, Straßenschlucht, Westseite
The need for EO data: Static Driver for PALM-4U

Digital Surface Model Munich from WorldView2
0.5 – 1.8 m spatial resolution
(Peter Reinartz und Pablo d’Angelo, DLR)

Static Driver for PALM-4U
Domain Landshuter Allee (1x1km²)
3D-Morphology, surface properties
urban green vegetation dynamics
Mapping Urban Green Space by EO

→ Official Cataster Data
Mapping Urban Green Space by EO
Mapping Urban Green Space by EO

Verkehrsbegleitgrün
Grünzüge
Grünflächen
Gärten bayerische Schlösserveraltung

Vegetation < 2m
Spärliche Vegetation
Vegetation 2m - 10m
Vegetation 10m - 20m
Vegetation 20m
Mapping Urban Green Space by EO

→ Urban Climate Modelling of Heat Stress needs realistic Data on Urban Green from EO Data!

Pilot: EO-based pollution-health risks profiling in the urban environment

• Develop and evaluate methodology in selected European cities
• Roll-out and transfer to any city worldwide lacking detailed information
Air Pollution and Health Risk Pilot: Munich Metropolitan Area

- **Co-Design:** Health and Environmental Authorities
- **Sustainability:** Embedded in Alpine Data Analysis Center and World Data Center for Remote Sensing of the Atmosphere
- **Pilot Access:** [https://www.alpendac.eu/eshape](https://www.alpendac.eu/eshape)
Bioclimatic Information System

(https://www.alpendac.eu/bioclis)

Co-Design & Users: Bav. State Ministry for the Environment, Bav. State Ministry for Health

Daily forecast (72h) + times series

Medical advice on behaviour & preventive measures for general public & people at risk
Plattform of Health Surveillance Air Quality Pilot (HSAQ)

Plattform coordinated by National Observatory Athens (NOA) to showcase global services and pilots
Take-Home Messages

EO data records enable consistent global monitoring of urban development and environments.

However, combining satellite remote sensing with numerical simulations is essential to develop livable, healthy and climate-resilient cities (UN SDG 3 and 11).

The urban climate model PALM-4U is unprecedented for studies under current and future climate conditions and traffic scenarios. It relies on EO data.

→ Strong need for integrated assessments of climate change and health risks in urban areas

→ Further development of tools and user-driven services in the context of EuroGEO (Co-Design)

→ Possible contribution to GEO’s Urban Heat and Health incubator
Striving for a continued uptake in science, planning and economy

Evidence-based policy advice and decision support

Knowledge and technology transfer
We look forward to contributing to GEO and EuroGEO

Thank you!
Disclaimer

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