EUROGEO WORKSHOP 2023

Global Urban Monitoring and Assessment of Environmental Health Risks

Thilo Erbertseder, Thomas Esch, Lorenza Gilardi, Tobias Leichtle, Ehsan Khorsandi, Mattia Marconcini and Hannes Taubenböck

DLR

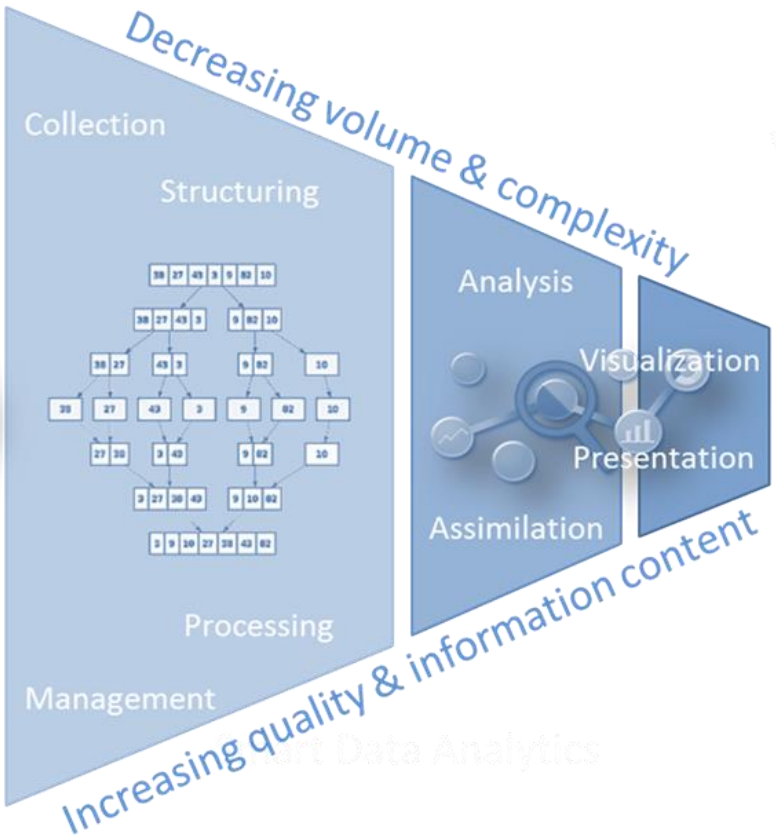
BOLZANO 2-4 OCTOBER 2023

eurac research

Institute of Atmospheric Pollution Research
National Research Council of Italy

European Commission

Global Urban Monitoring from Space



Technology and Data for Sustainable and Resilient Future Cities

User Needs → Co-Design → Implementation → Sustainability

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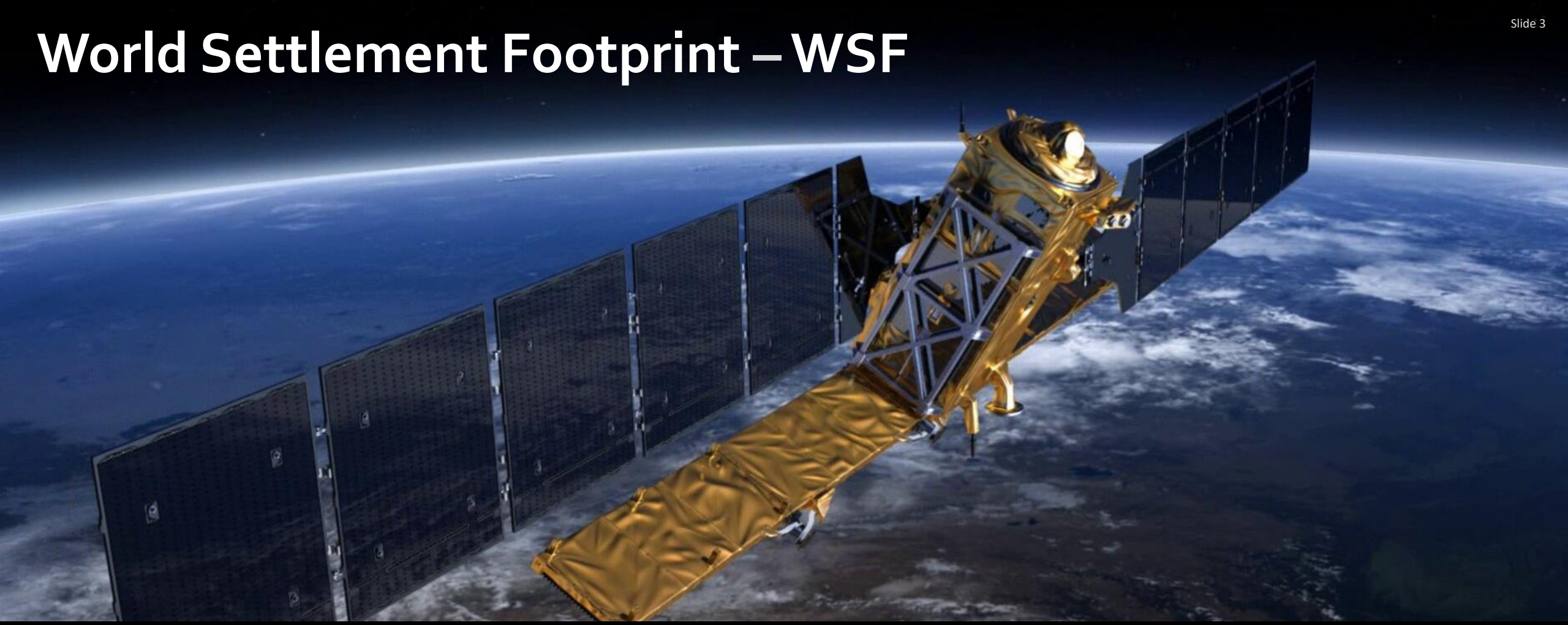
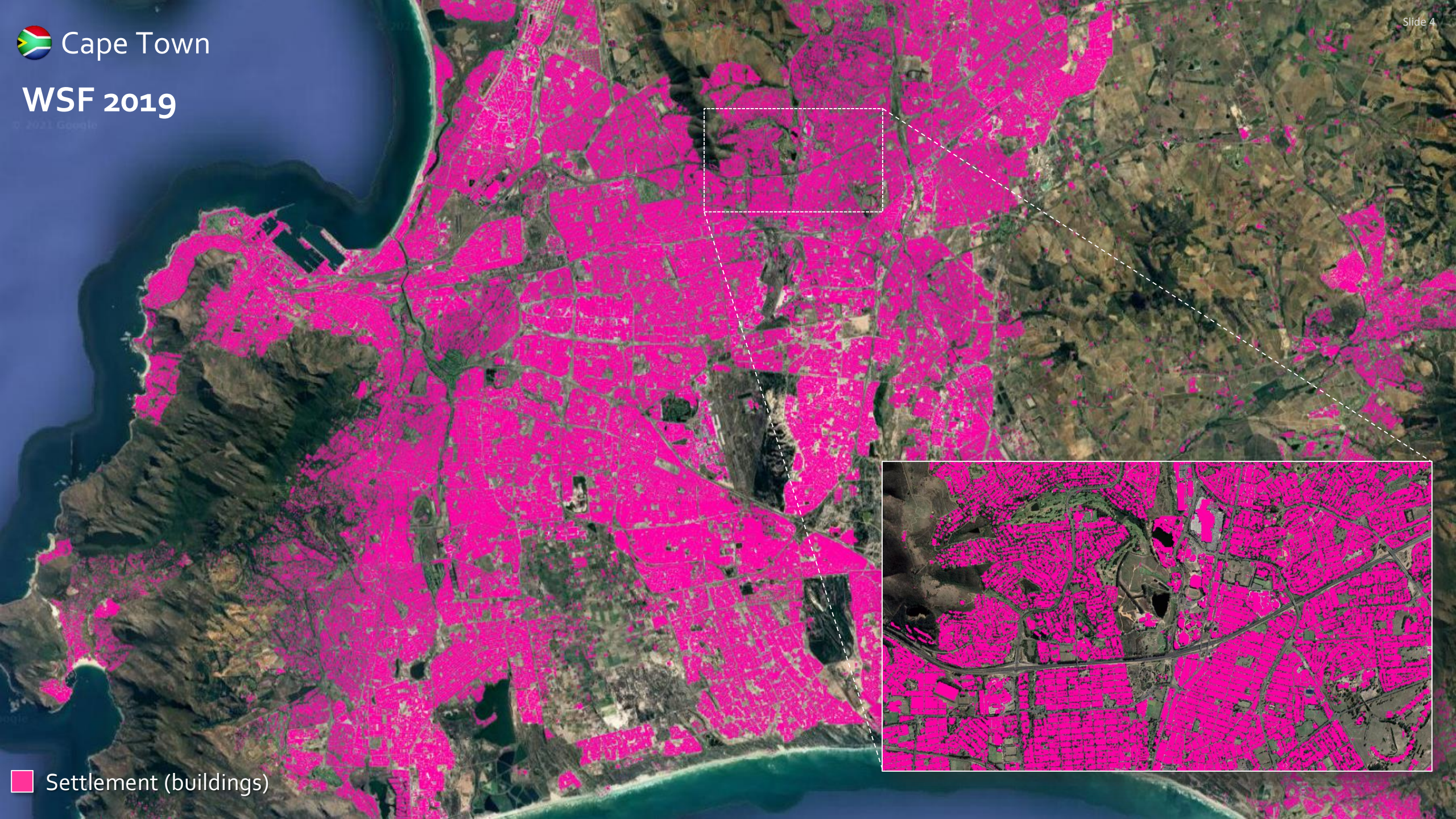
World Settlement Footprint – WSF



WSF	**Settlement extent 2015, 2019**	**Sentinel 1, Sentinel 2**	**10 m ground resolution**
WSF imperviousness	**Percent impervious surface 2019**	**Sentinel 2, WSF**	**10 m ground resolution**
WSF population	**Population distribution 2019**	**WSF imp, population stats**	**10 m ground resolution**
WSF evolution	**Settlement growth 1985 – 2015 (annual)**	**Landsat, WSF**	**30 m ground resolution**
WSF 3D	**Building height and volume 2019 (2012)**	**TanDEM-X, WSF**	**90 m ground resolution**

Cape Town

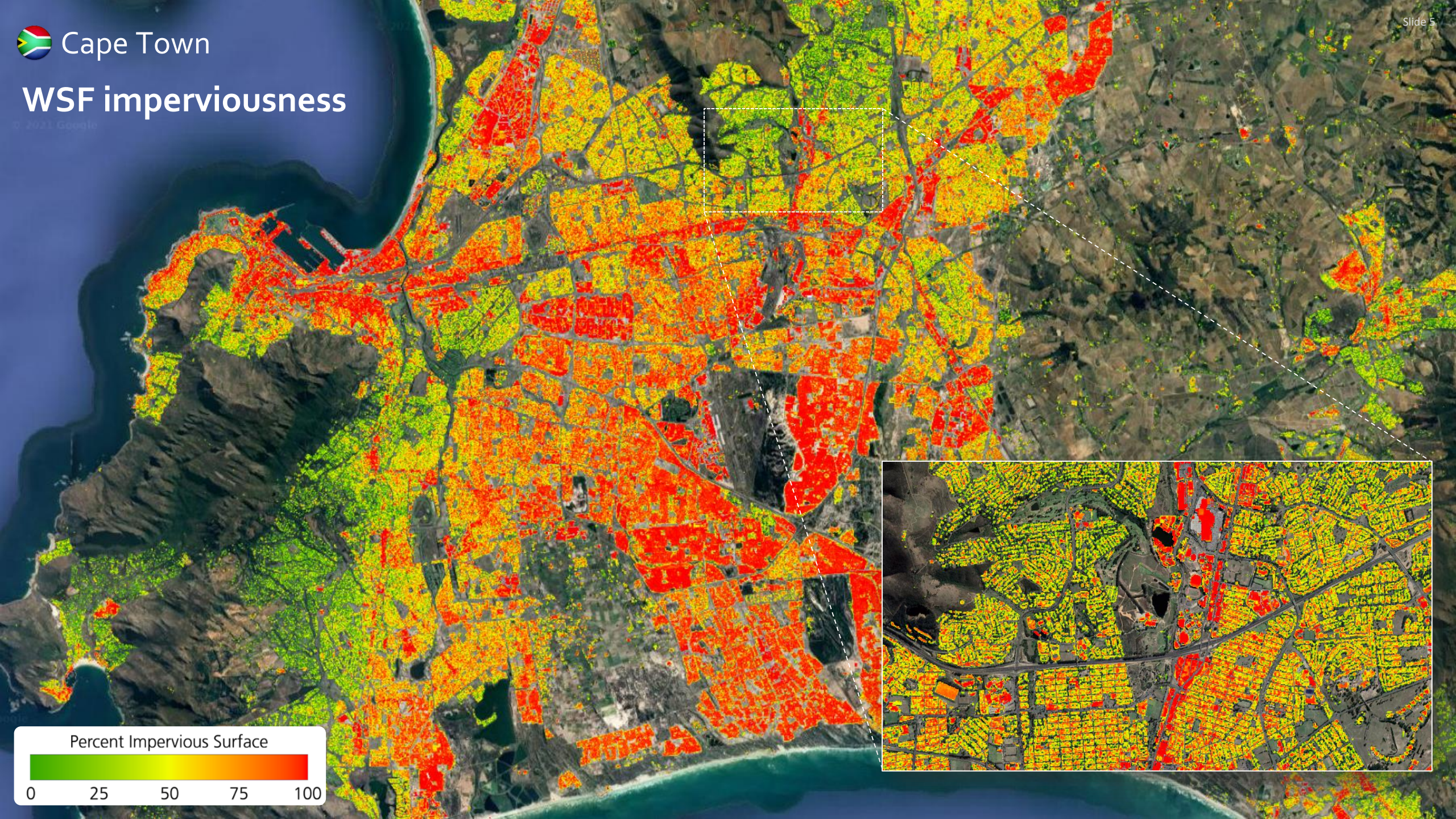
WSF 2019



Settlement (buildings)

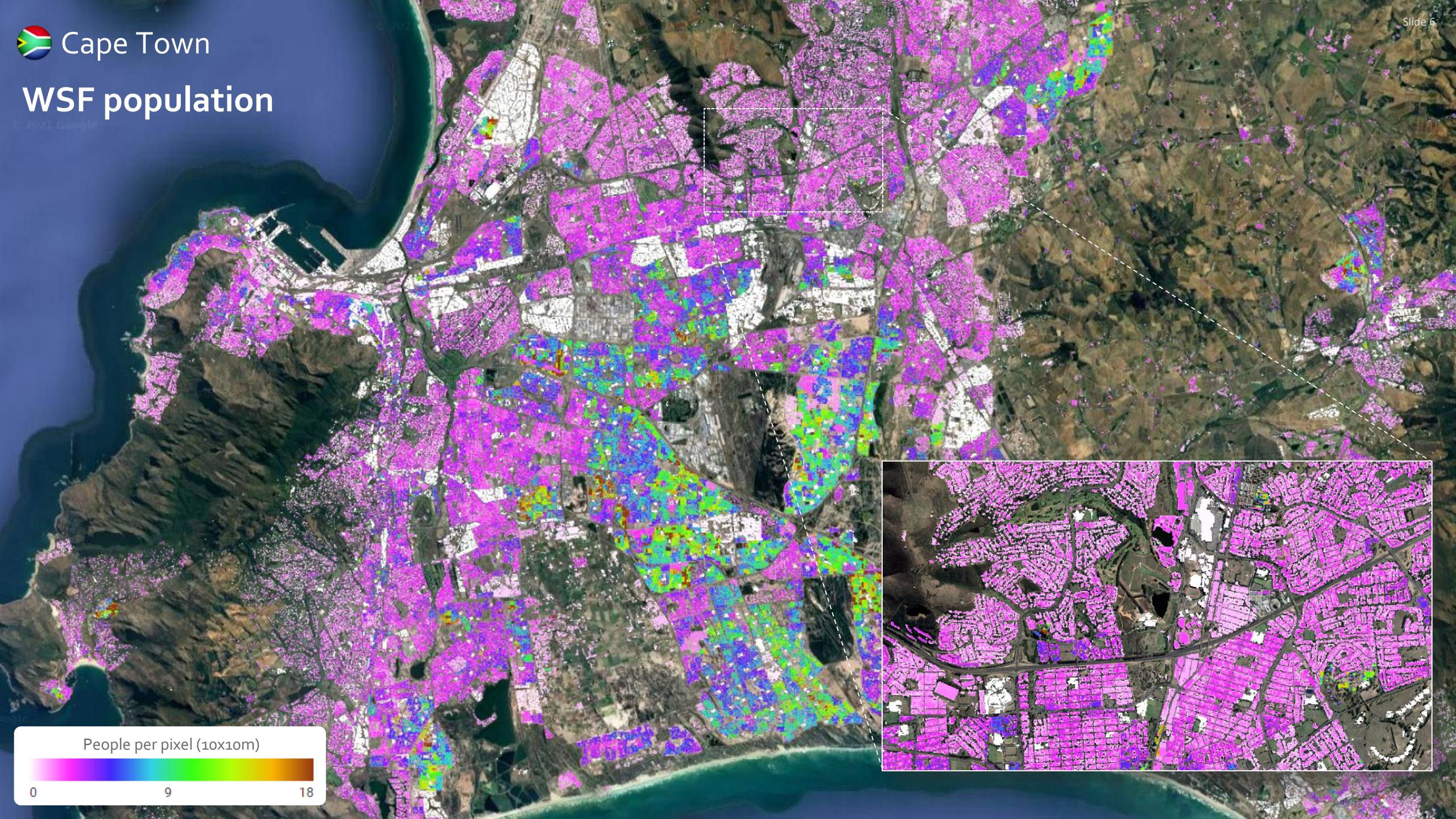
Cape Town

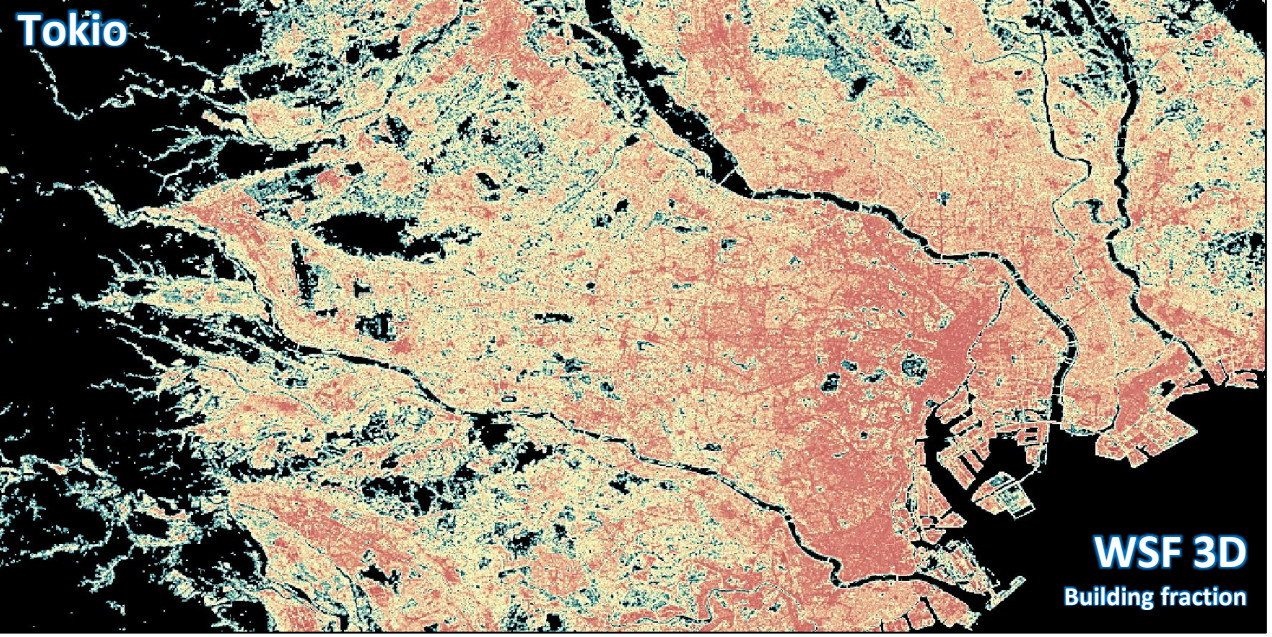
WSF imperviousness

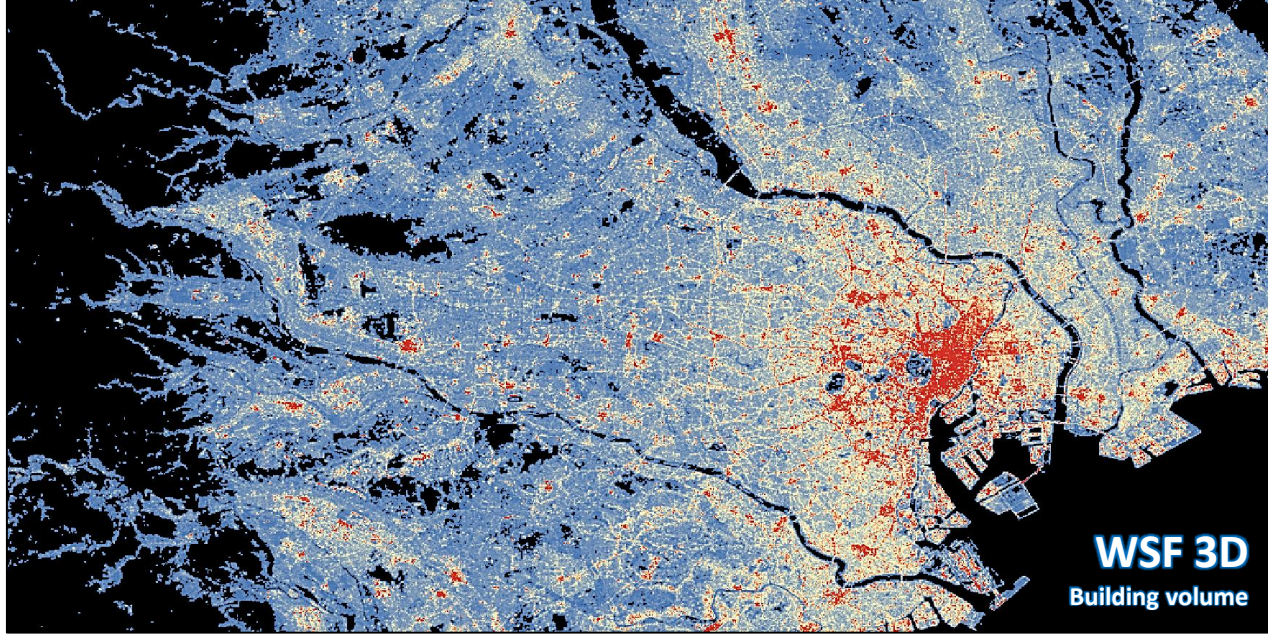


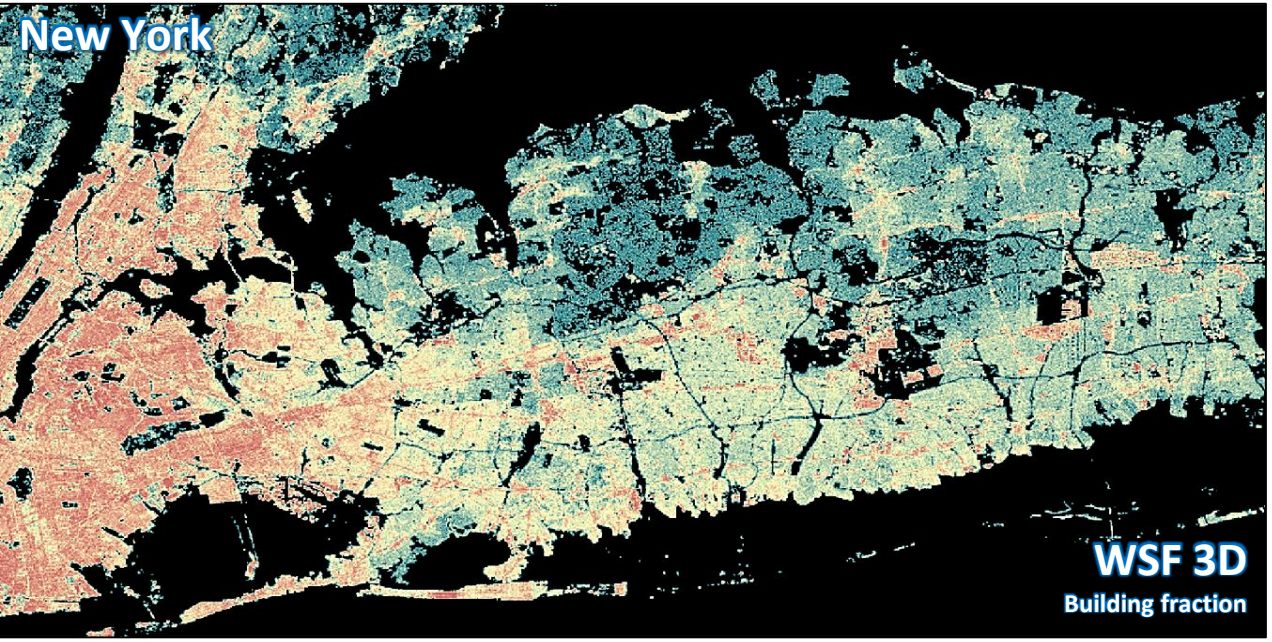
Cape Town

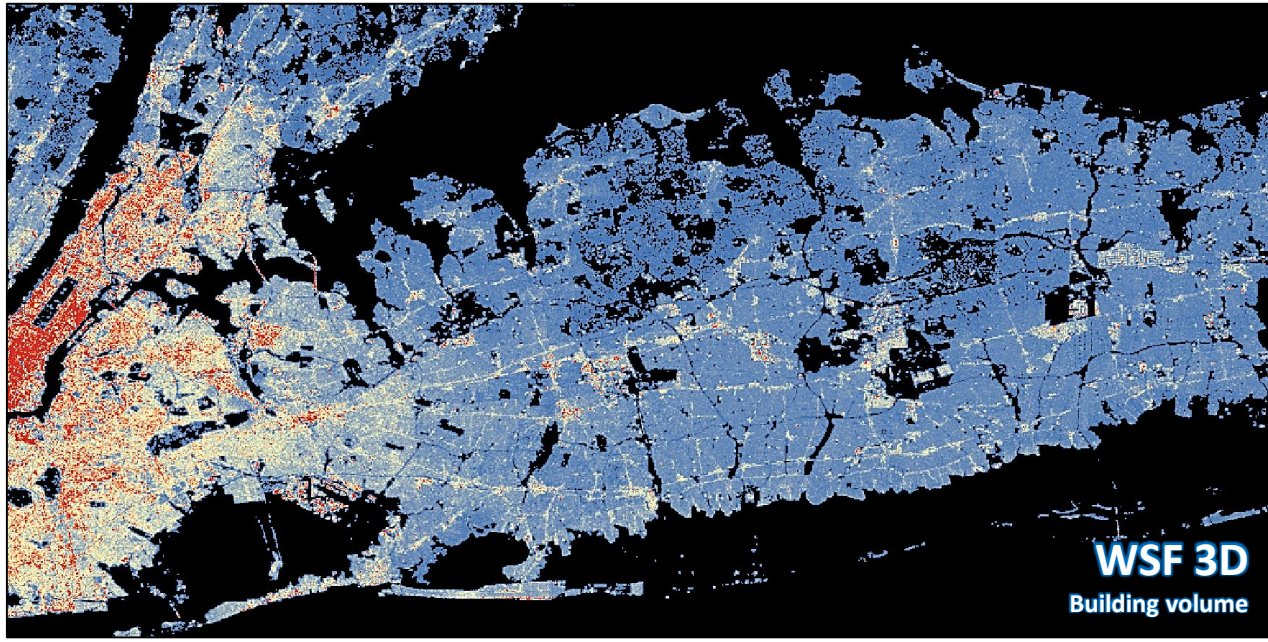
WSF population











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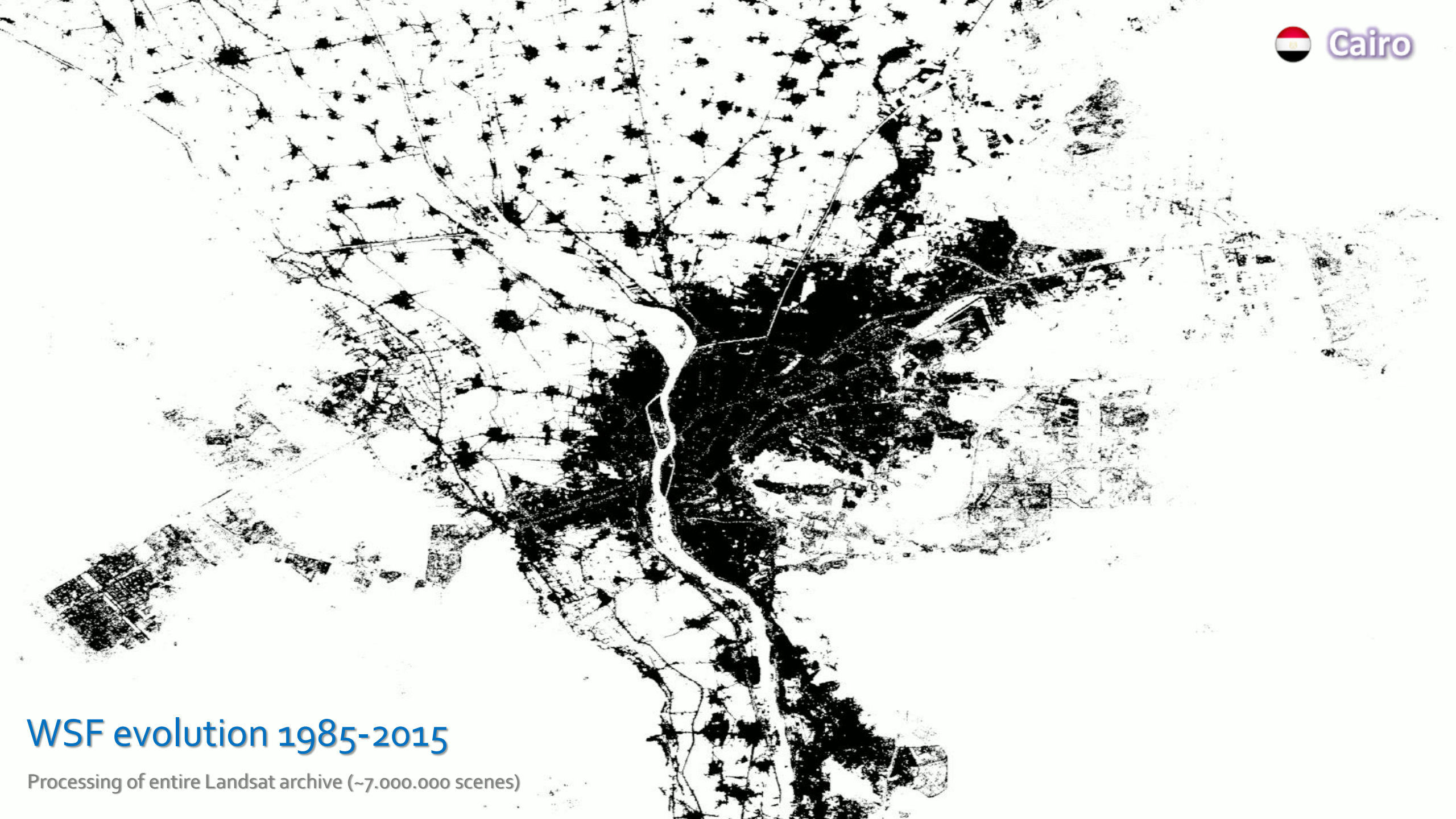
Fraction
0 100
[%]

Volume
Low High
[m^3]

First worldwide 3D mapping of the built environment (Esch et al., 2023)

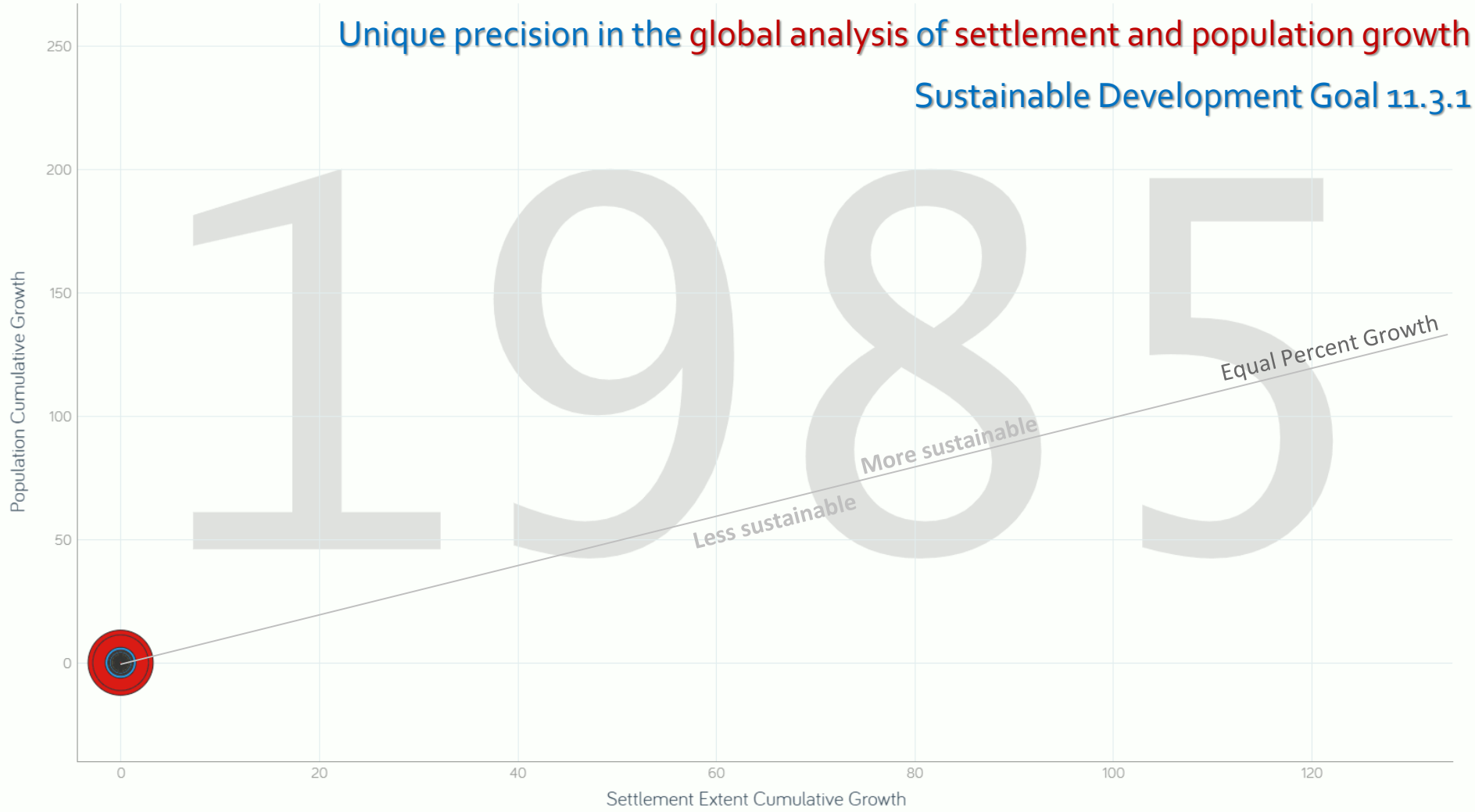


WSF evolution 1985-2015

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



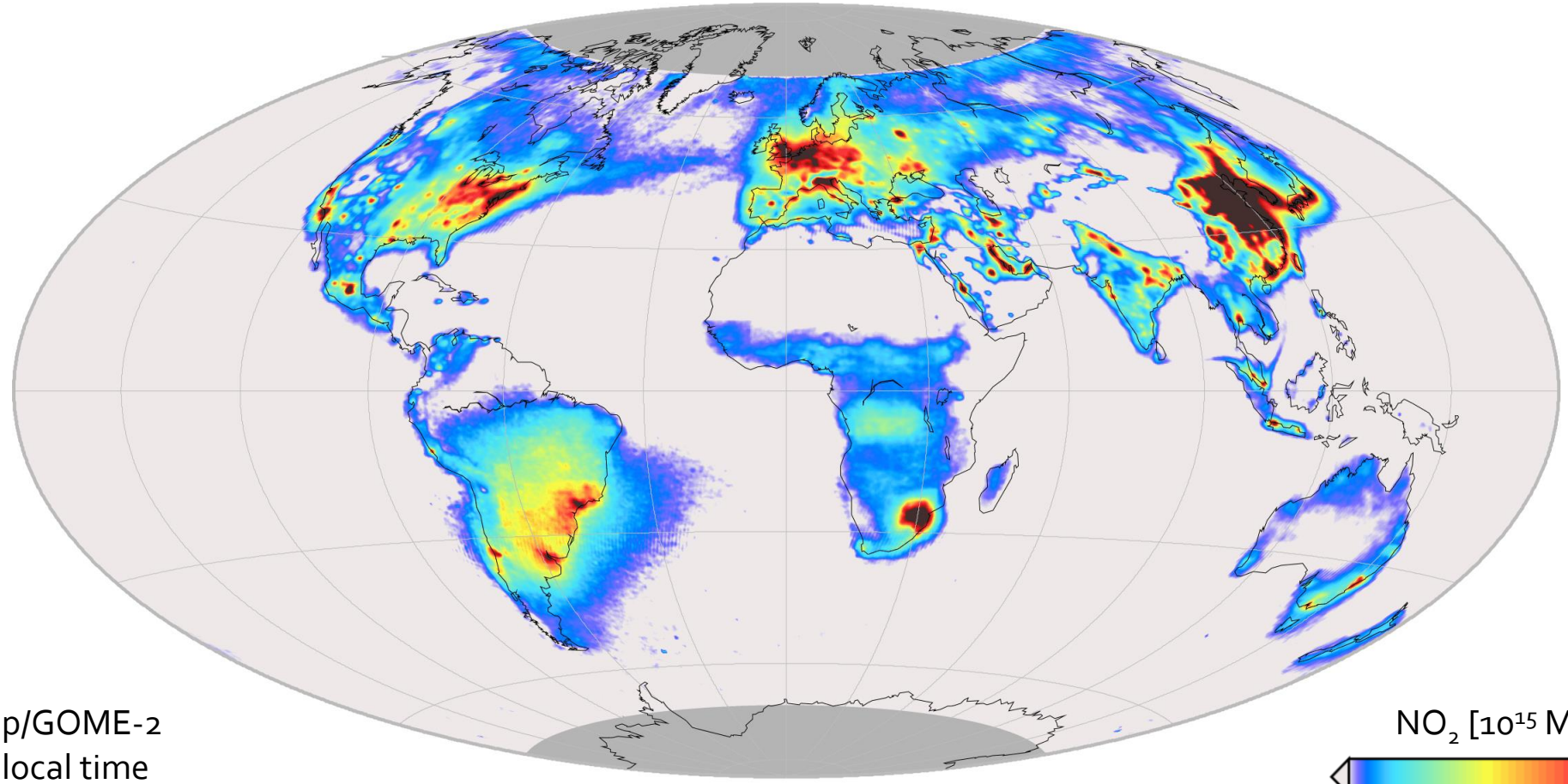
High income country Upper middle income country Lower middle income country Low income country

Size of the circles proportional to log(total population)

DLR

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

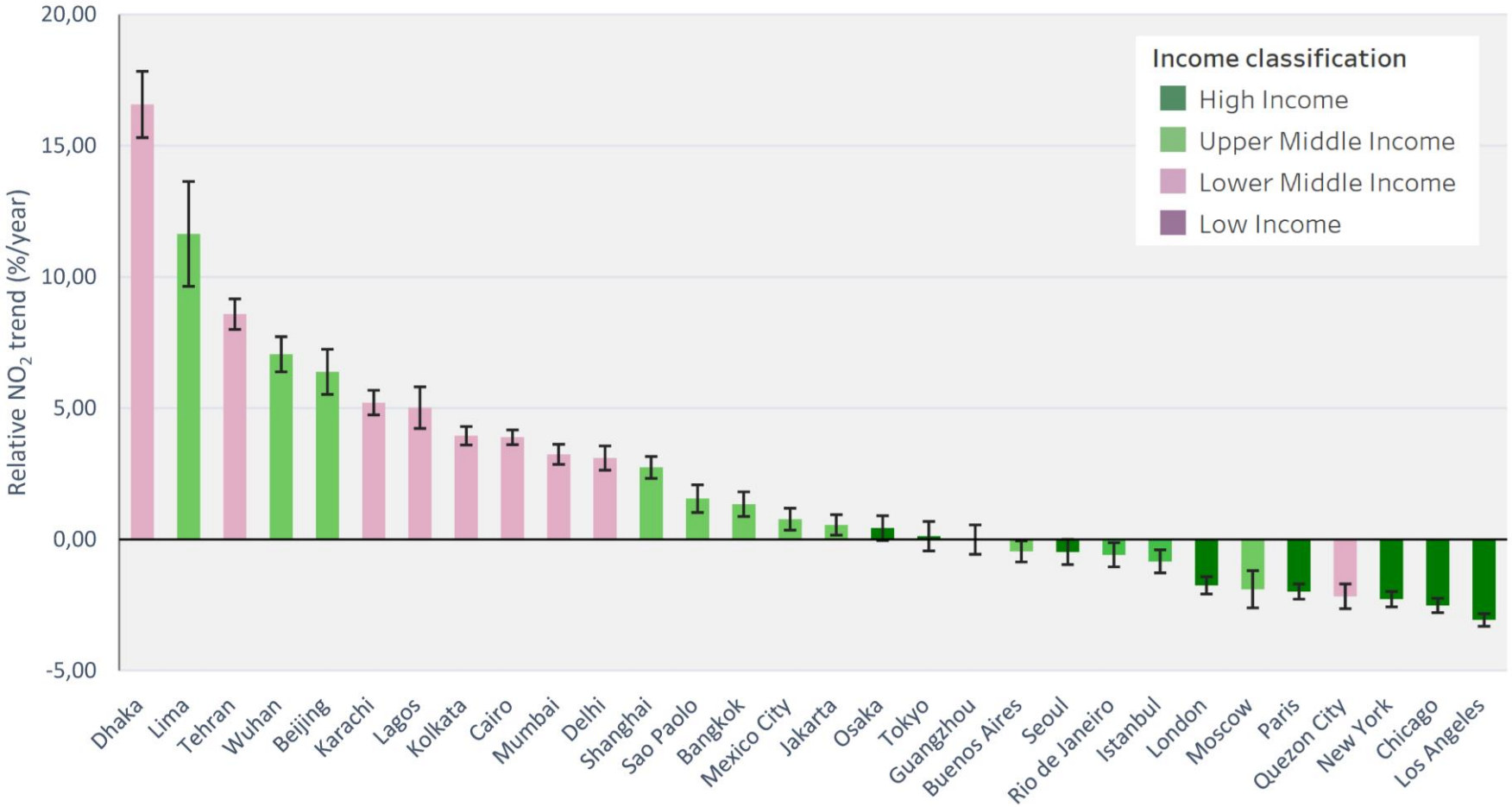
NO_2 [10^{15} Molecs/cm²]

1 2 3 4 5

Erbertseder et al., 2015 (updated)

Relative NO2 Trends for Megacities (%/year)

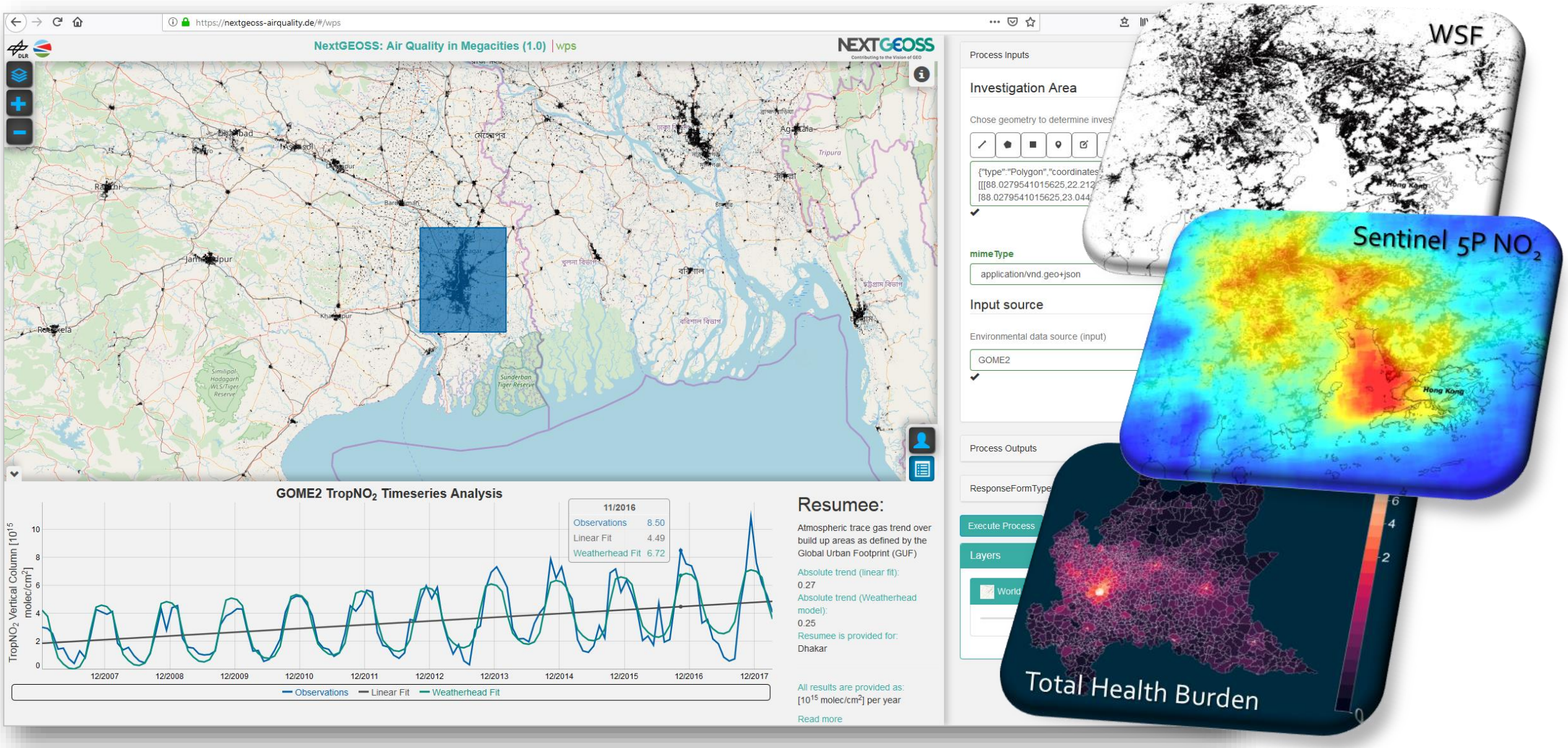
Period covered: 1996 - 2015



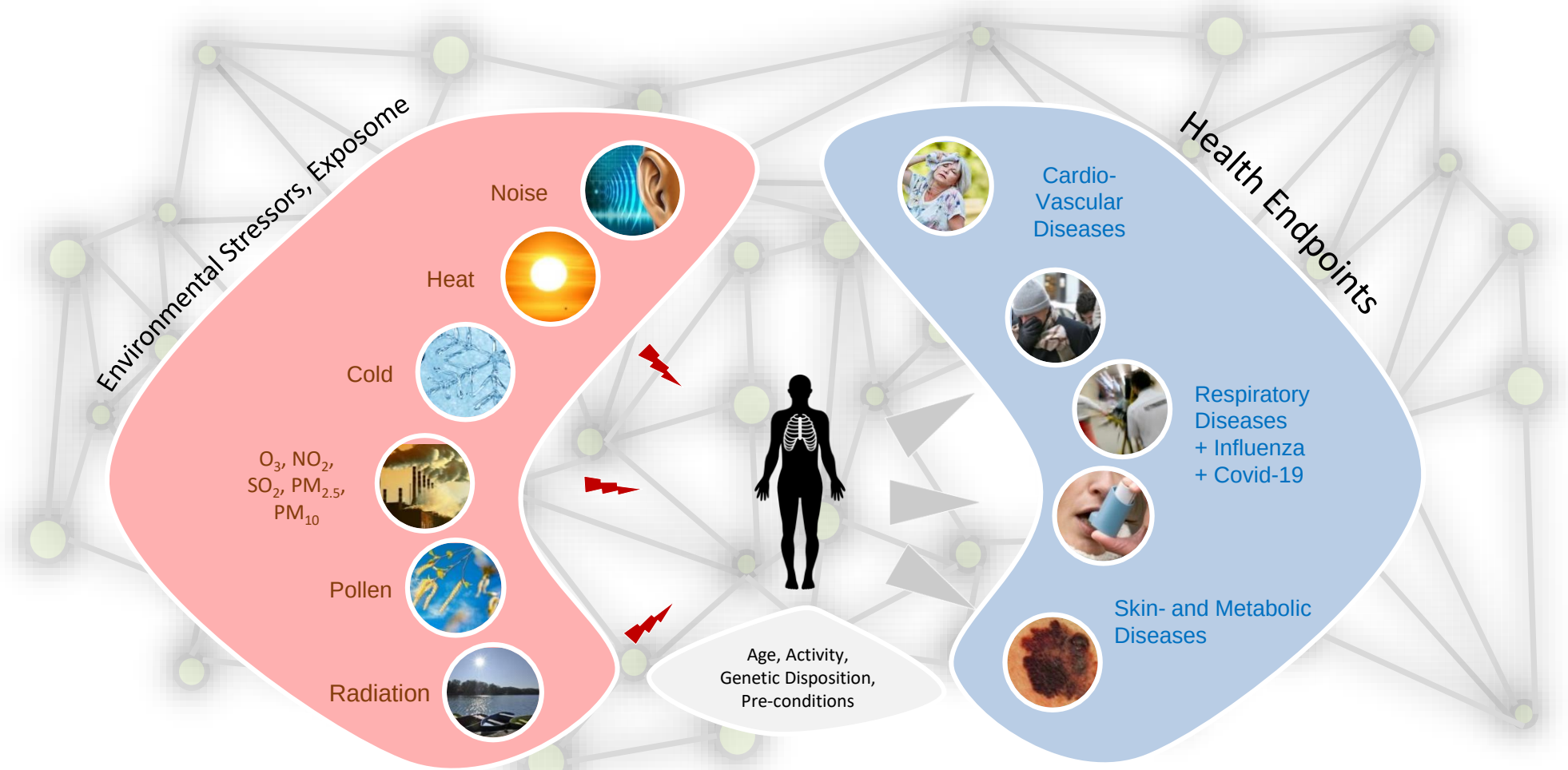
Income groups indicated according to world's economies classification of the World Bank (2022)

Erbertseder, T., Taubenböck, H., Esch, T., Gilardi, L., Paeth, H., Marconcini, M. and S. Dech (2023): EO-based analysis of NO2 pollution and settlement growth in megacities, *2023 Joint Urban Remote Sensing Event (JURSE)*, Heraklion, Greece, 2023, pp. 1-4, doi: 10.1109/JURSE57346.2023.10144190

NextGEOSS Pilot: Data and Information Fusion on Demand

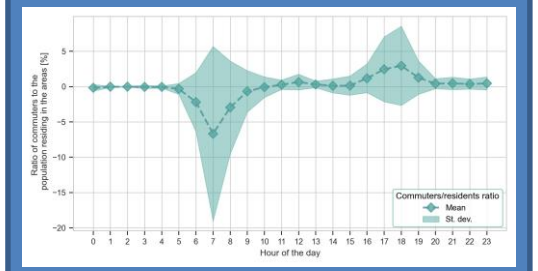


Integrated Assessment of Urban Climate and Health Risk

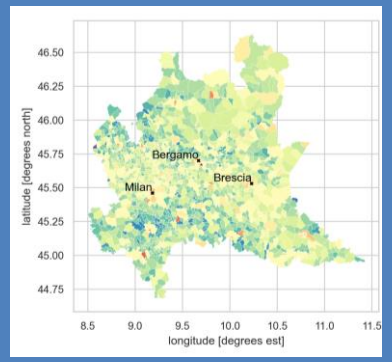


Health risk assessment from air pollution – impact of mobility

Mobility Patterns



Day vs night **population**



Study region: Lombardy, Italy

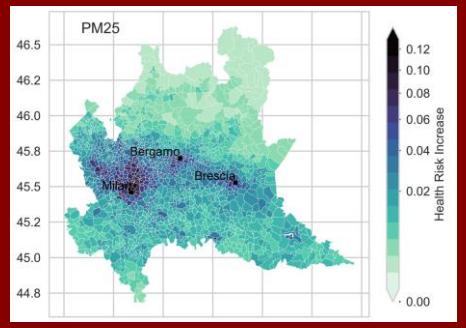
Probability of exposure

- 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

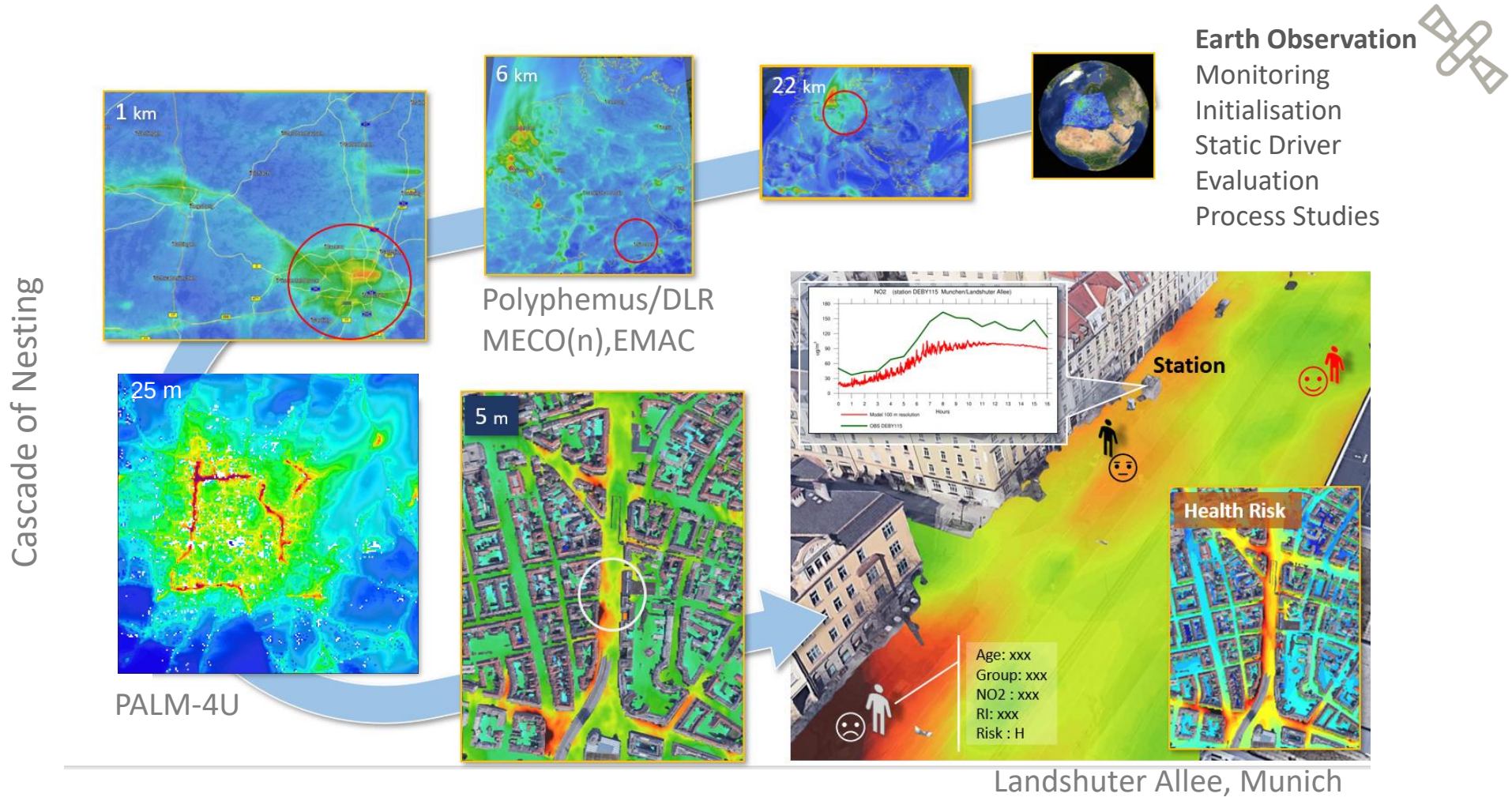
Long-term DAY and NIGHT **Health Risk Increase** (HRI)



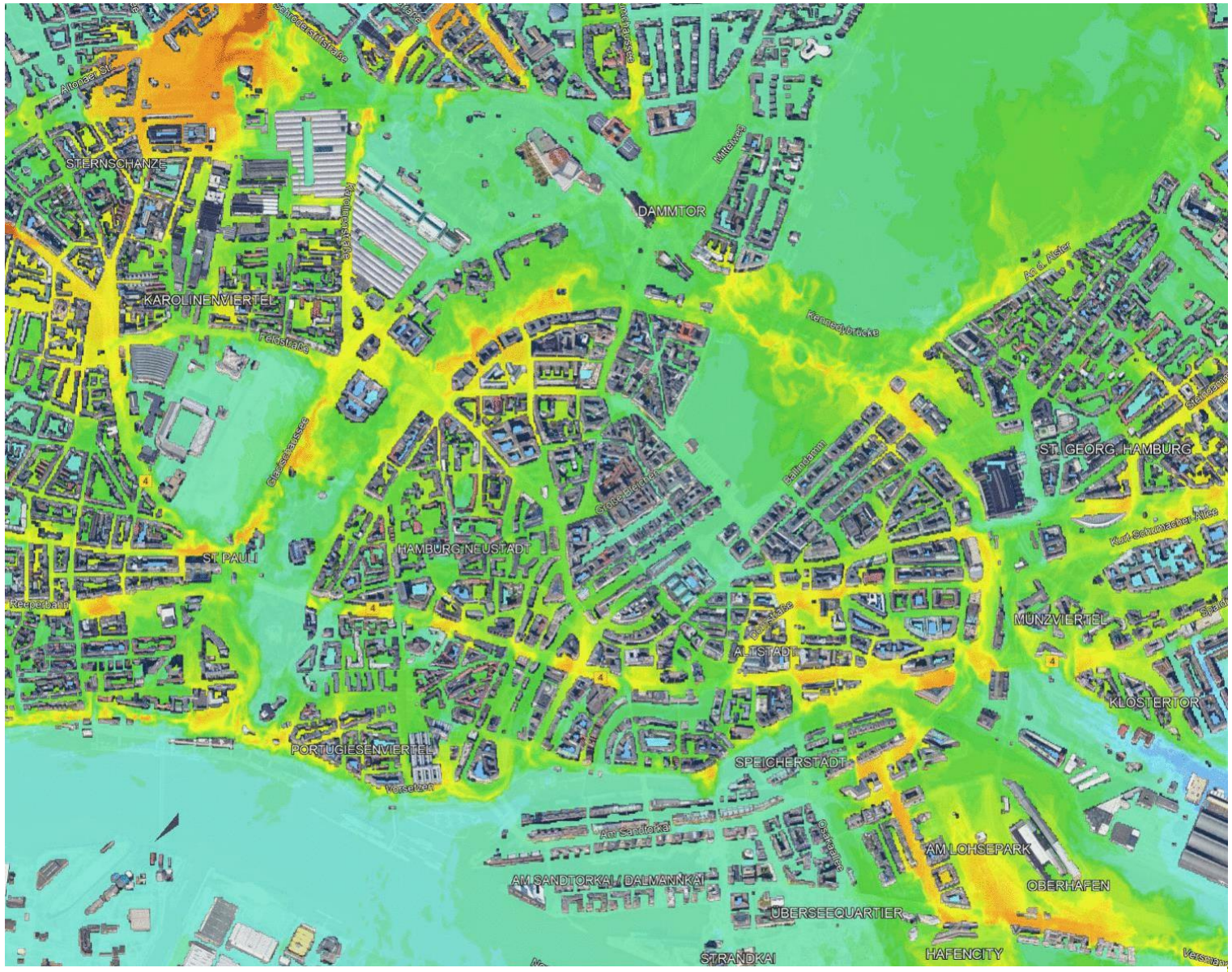
Health Risk from PM2.5 NO2 and O3 exposure **increases** when considering a **dynamic (commuting) population.**

Gilardi, L., Marconcini, M., Metz-Marconcini, A., Esch, T. and T. Erbertseder: Long-term exposure and health risk assessment from air pollution: impact of regional scale mobility, *International Journal of Health Geographics, 22*(1), 11. doi:10.1186/s12942-023-00333-8. 2023

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



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

Erbertseder, T., Matthias, V., Krajzewicz, D., Mertens., M., Badeke, R., Baier, F., Handschuh, J., Khorsandi, E., Ramacher, M., Quante, M., Thaller, C., Righi, M.: Der Einfluss verschiedener Verkehrsträger auf die Luftqualität von Hamburg, Immissionsschutz, 3/2023, https://doi.org/10.37307/j.1868-7776.2023.03.04

NO_2 [ppm]

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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

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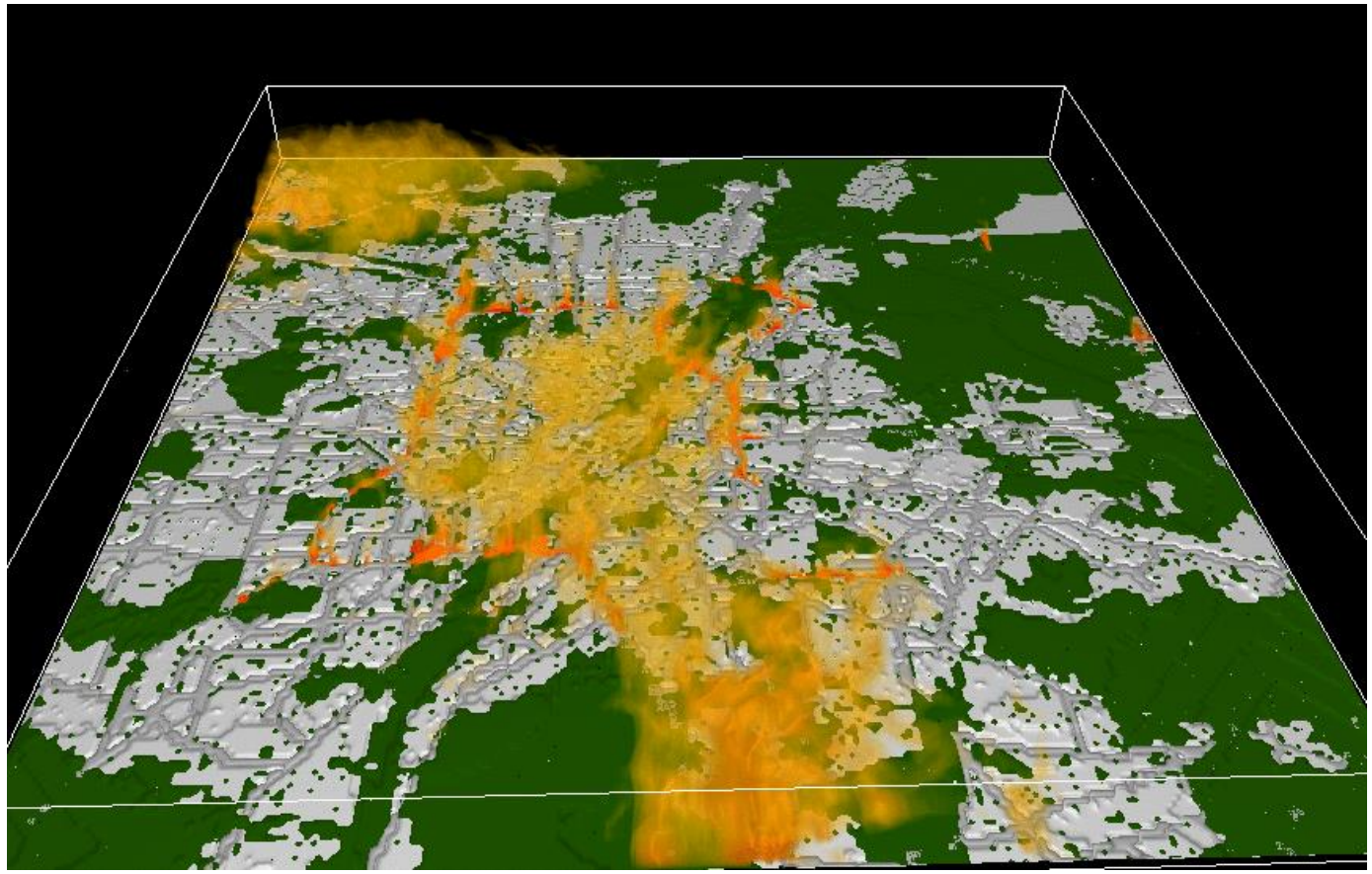
Bundesministerium für Bildung und Forschung

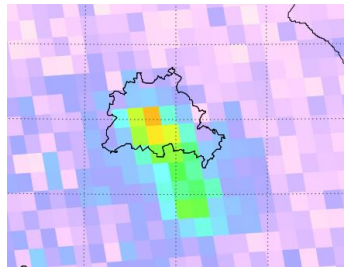
PALM-4U Simulations for Entire Cities (Munich)

FONA
Forschung für Nachhaltigkeit



NO_2, 20 Aug 2020, 12 – 16 (3D-Distribution)

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)



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für Bildung
und Forschung

PALM-4U - Hot Spot Landshuter Allee, Munich

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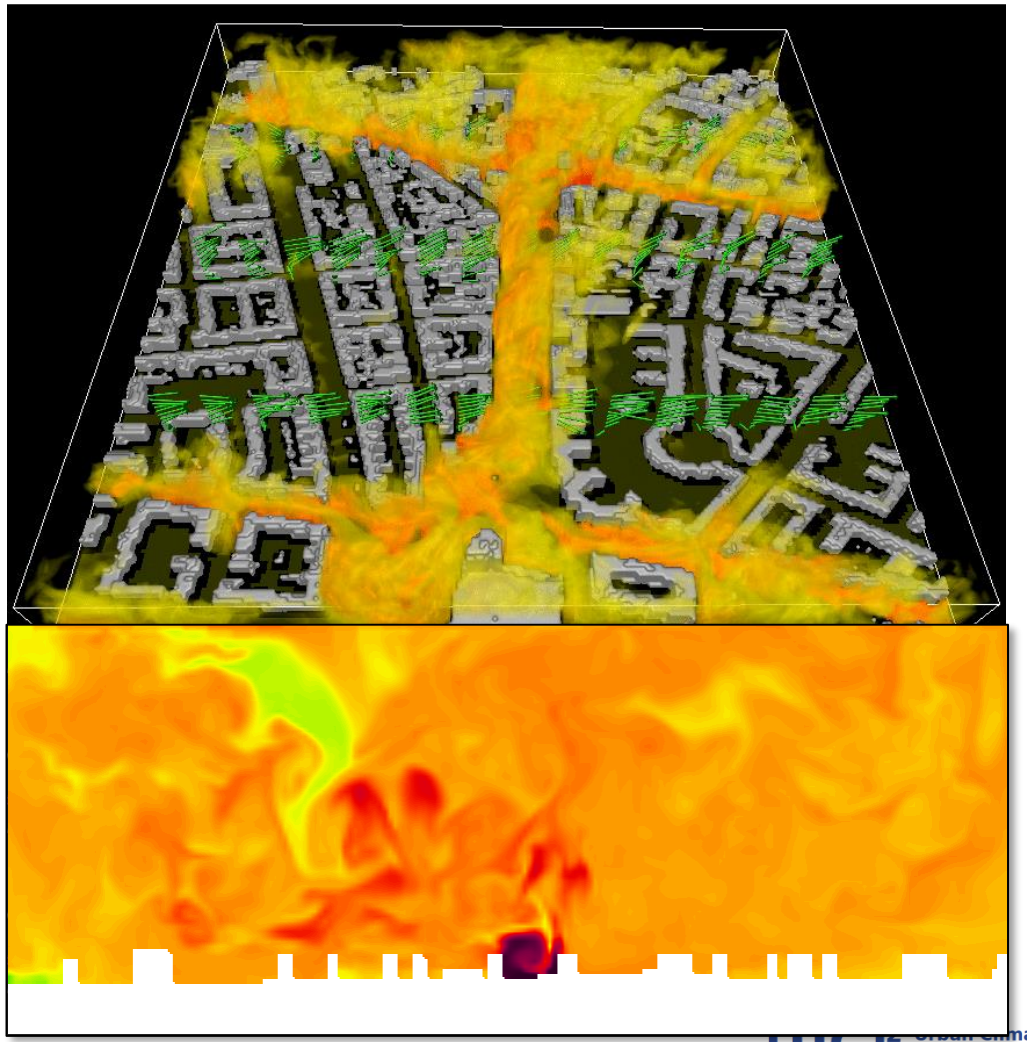
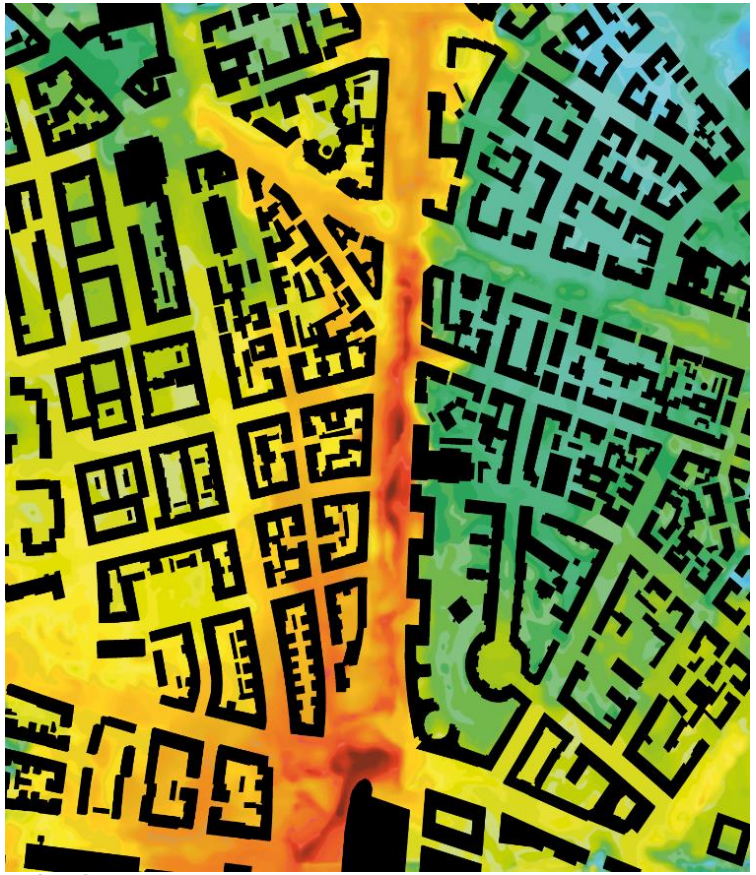
Forschung für Nachhaltigkeit



Recirculation effects in street canyons



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[UC]² Urban Climate Under Change
Stadtklima im Wandel

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für Bildung
und Forschung

Assessment of Thermal Stress

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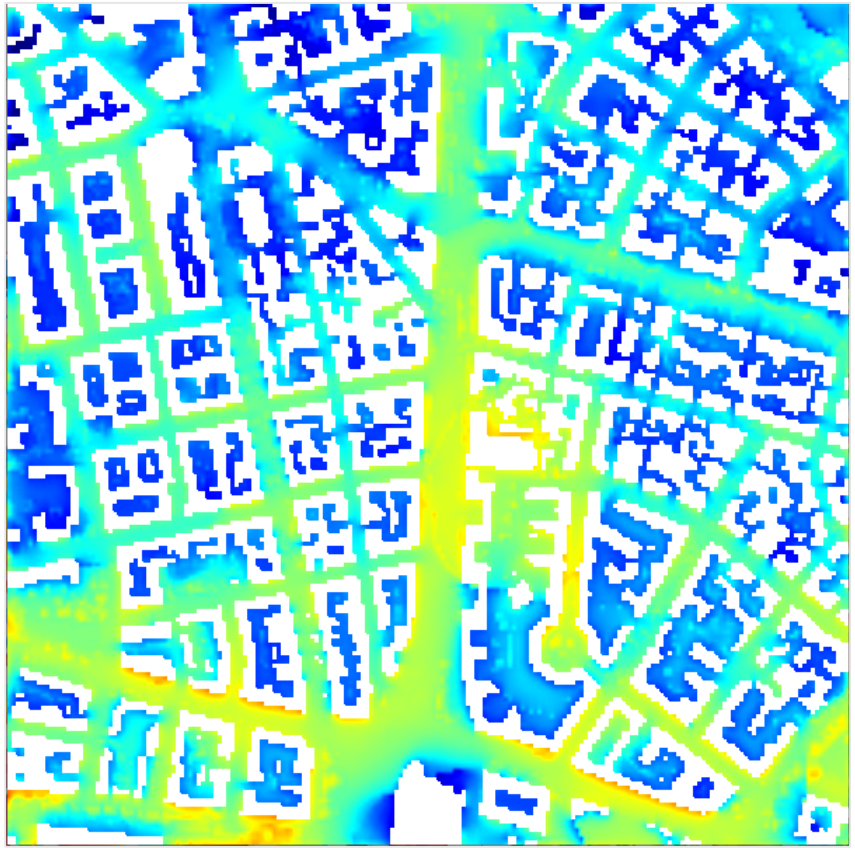
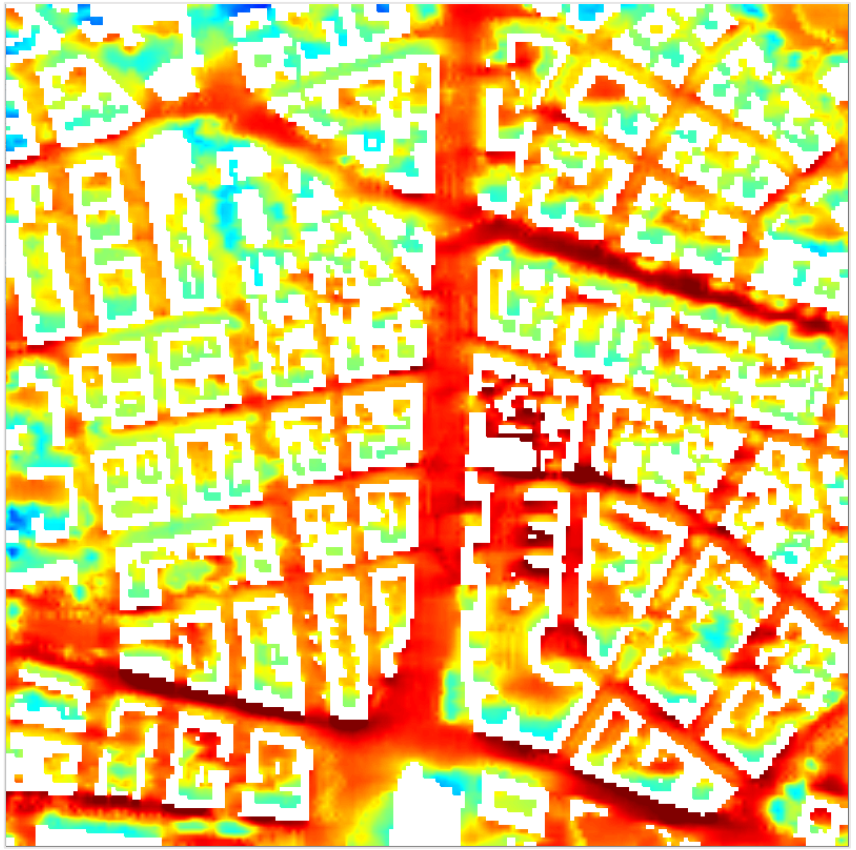
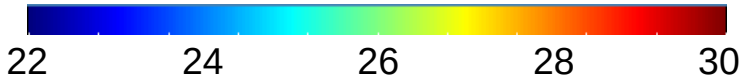
Air Temperature



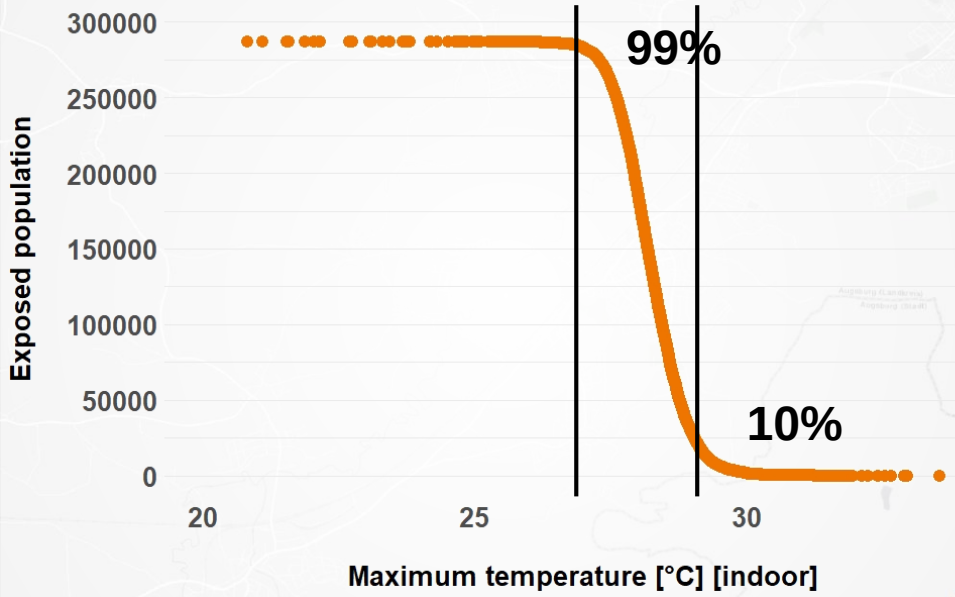
Thermal Stress (UTCI)



20.-21. August 2020, 48h Mean [°C]



Indoor extremes during a heatwave



Leichtle T, Kühnl M, Droin A, Beck C, Hiete M & Taubenböck H (2023): Quantifying urban heat exposure at fine scale - modeling outdoor and indoor temperatures using citizen science and VHR remote sensing. Urban Climate 49, 101522.

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Spatial and Temporal Variability of Heat Stress

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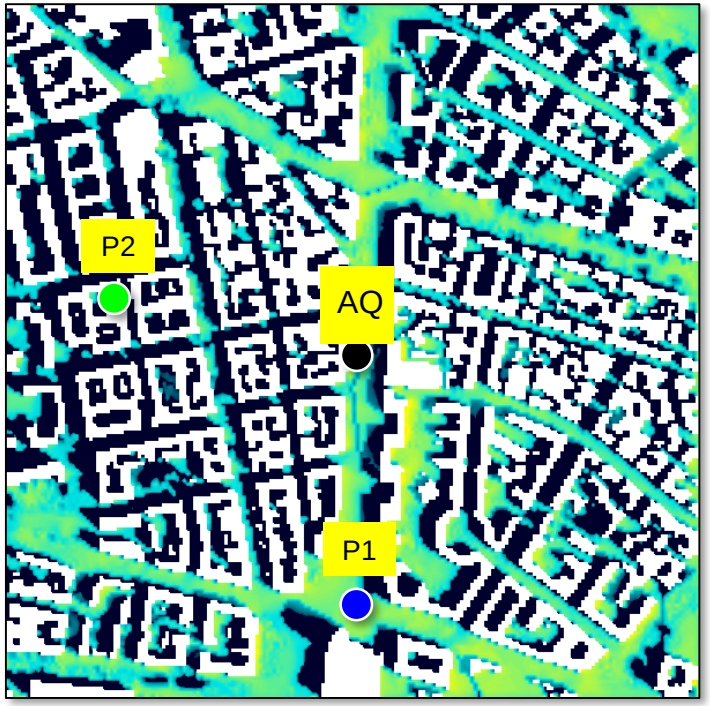
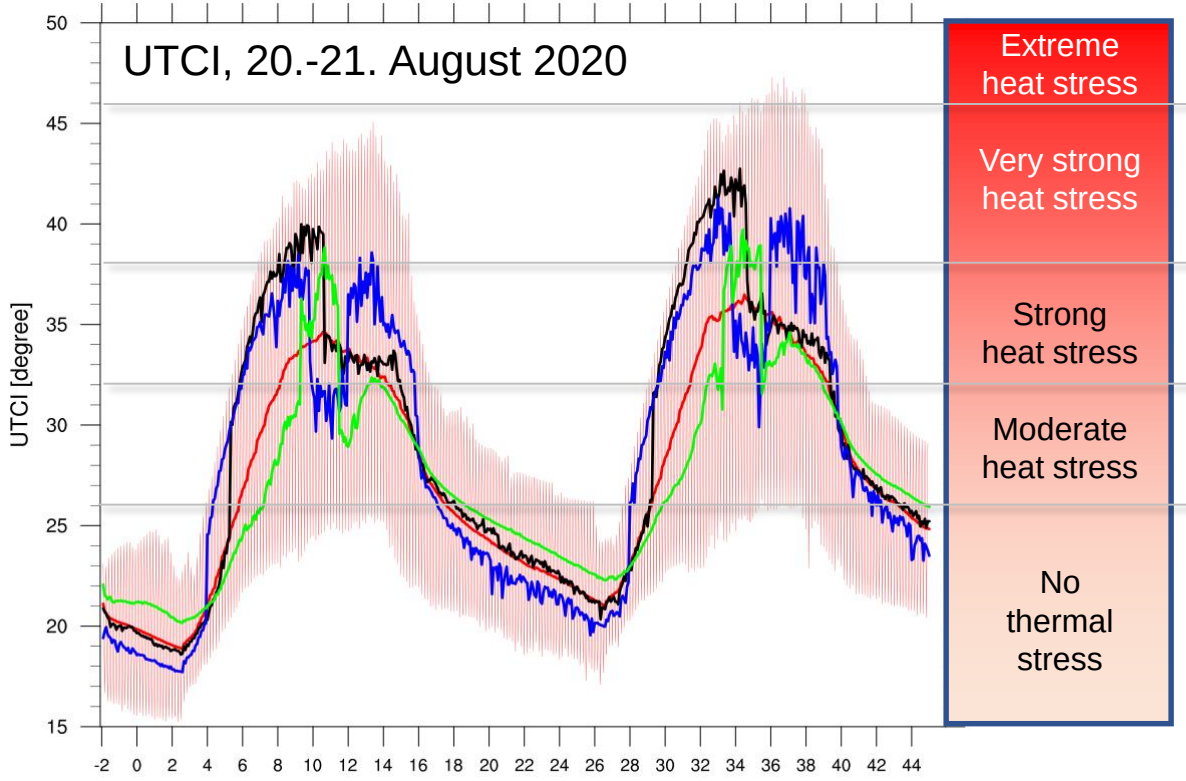
Forschung für Nachhaltigkeit





P1 Verschattung durch Hochhaus (Mercedes)
P2 Innenhof Wohnblockrandbebauung
AQ Luftmessstation, Straßenschlucht, Westseite

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und Forschung

The need for EO data: Static Driver for PALM-4U

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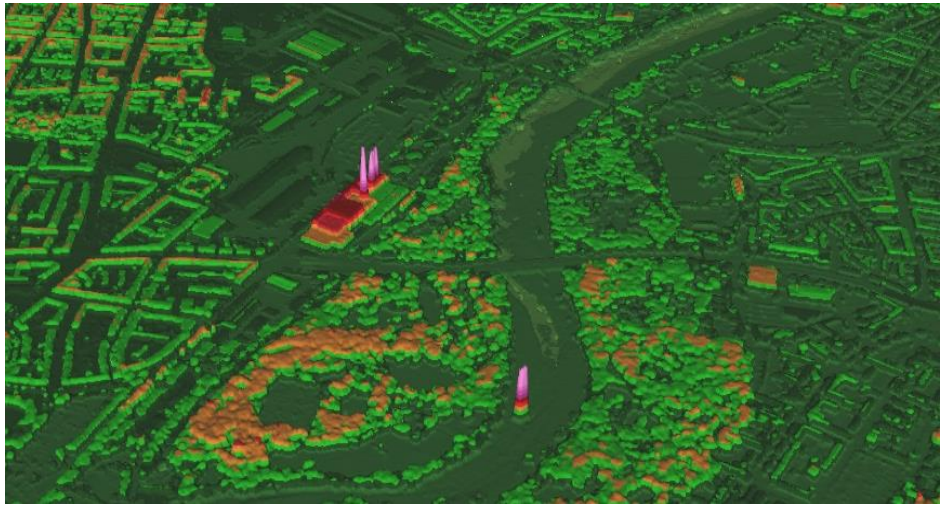
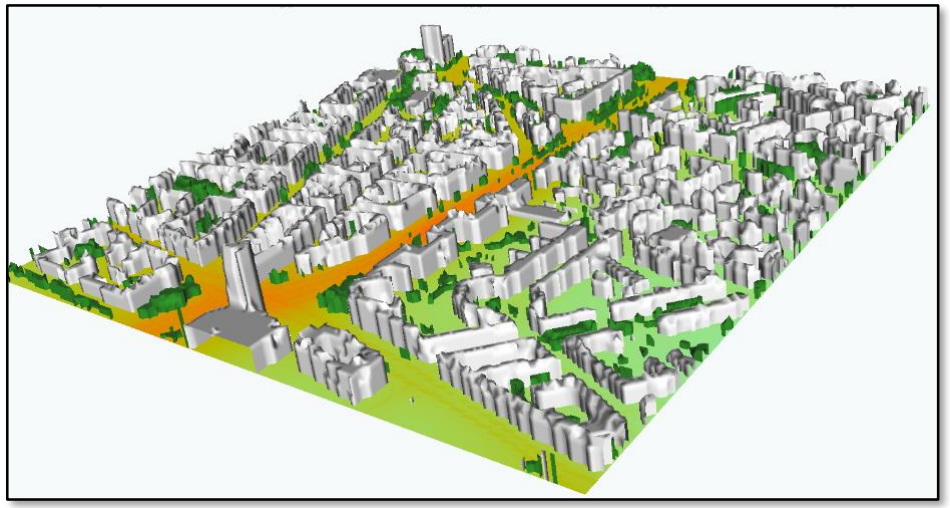
Forschung für Nachhaltigkeit



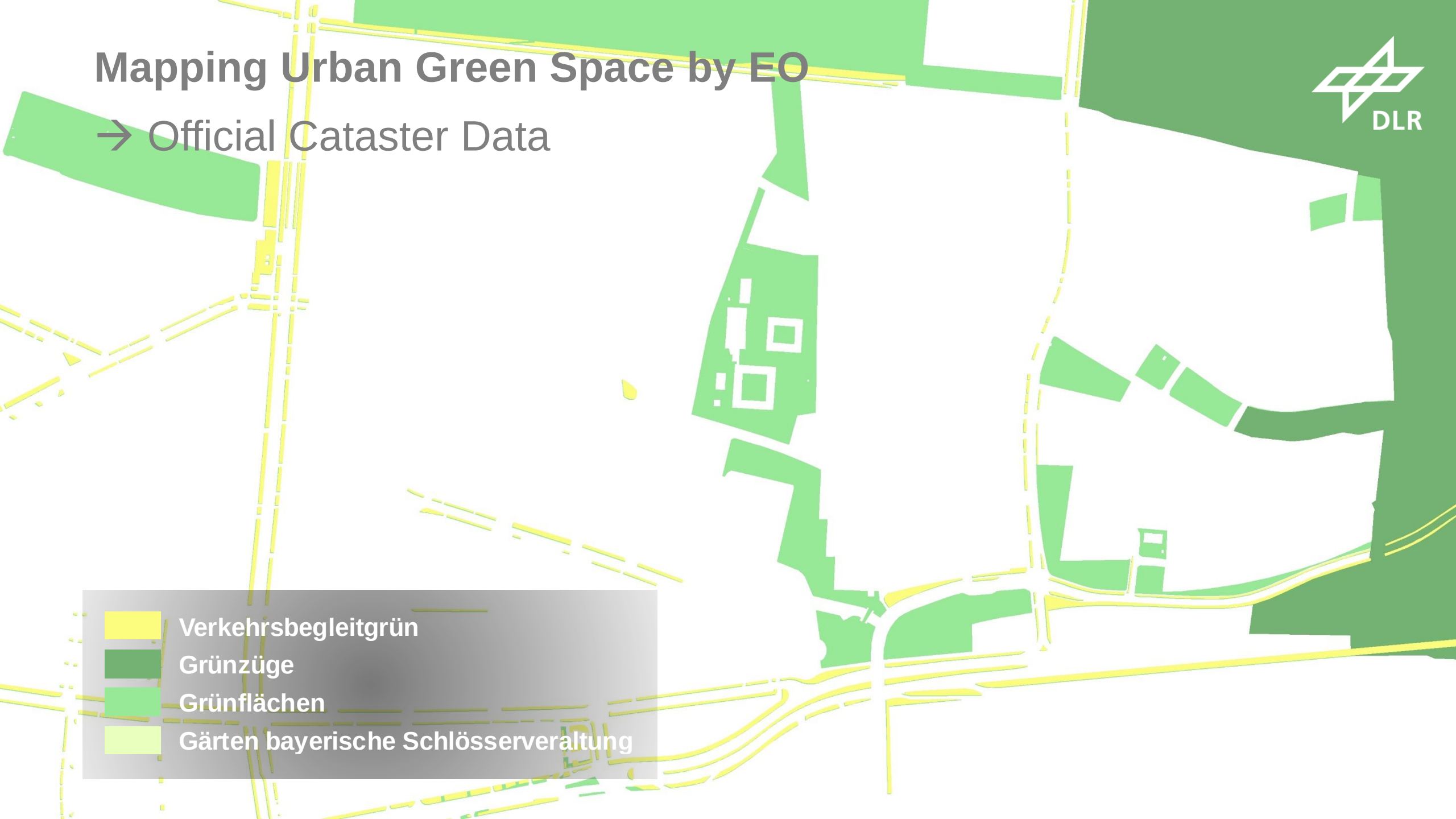
Digital Surface Model Munich from WorldView2
0.5 – 1.8 m spatial resolution
(Peter Reinartz und Pablo d'Angelo, DLR)



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

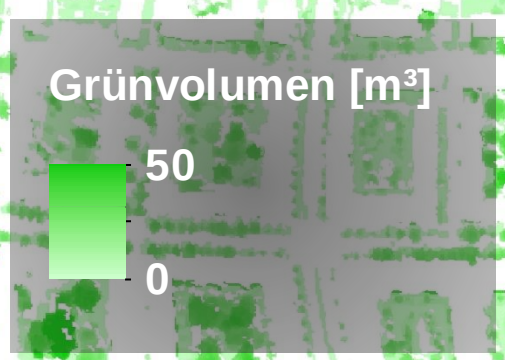


Mapping Urban Green Space by EO

Mapping Urban Green Space by EO

Mapping Urban Green Space by EO

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



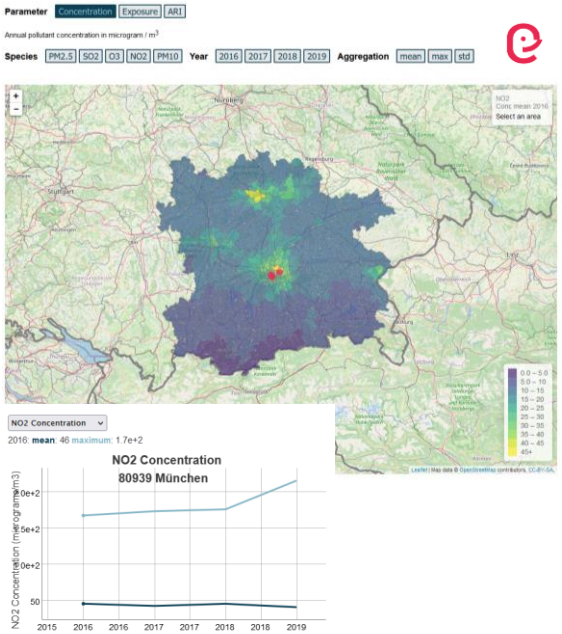
Leichtle T, Zehner M, Kühnl M, Martin K & Taubenböck H (2021): Urban Trees - Detection, Delineation, Quantification, and Characterisation based on VHR Remote Sensing. In: Proceedings of the REAL CORP 2021, 1029-1039.

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

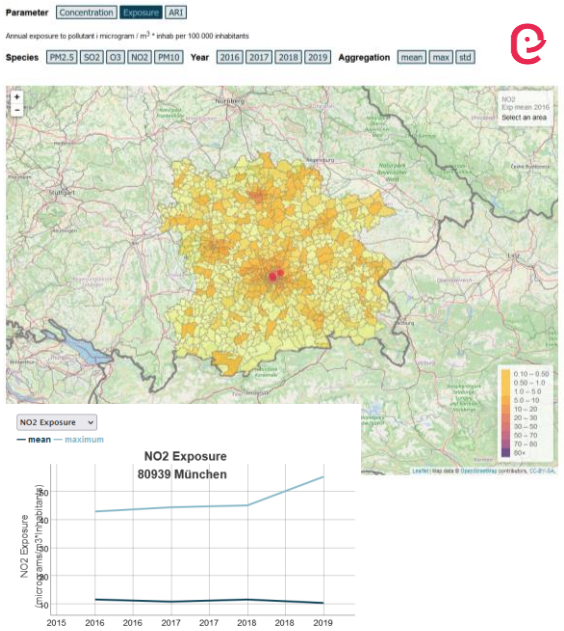
- Develop and evaluate methodology in selected European cities
- Roll-out and transfer to any city worldwide lacking detailed information

Air Pollution and Health Risk Pilot: Munich Metropolitan Area

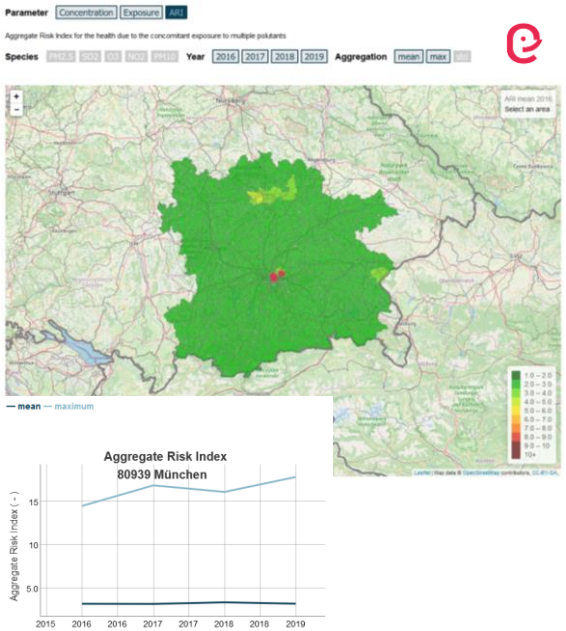
Pollutant concentrations



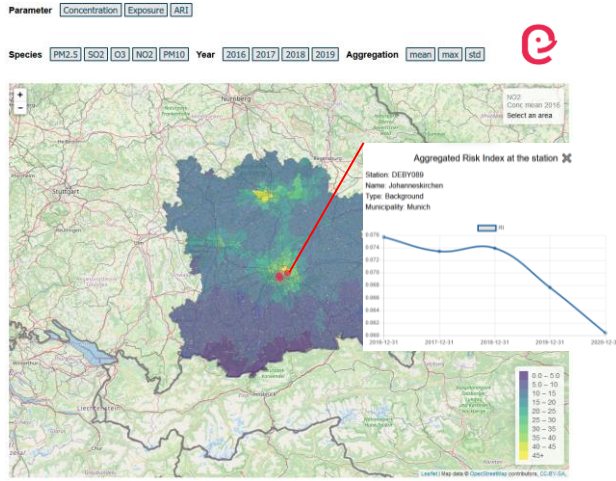
Population weighted exposure



Aggregate Risk Index



Aggregate Risk Index at stations



- 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

Bioclimatic Information System

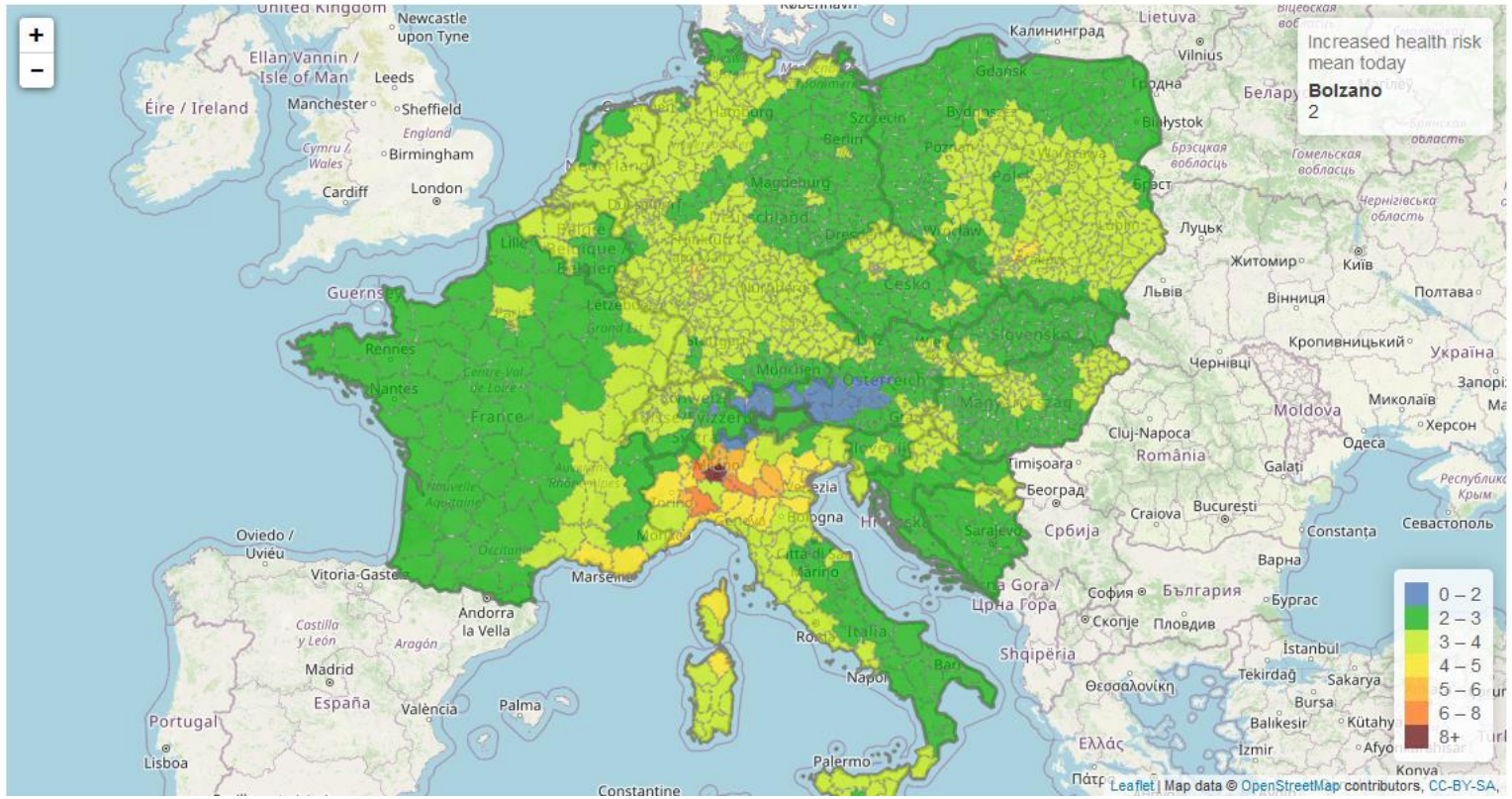
(https://www.alpendac.eu/bioclis)

Parameter ARI | UTCI | O3 | NO2 | PM10 | PM2.5 | SO2 | dTmrt

ARI Aggregated Increased Health RIsk Index

Describes the increased health risk from air pollution - See below for health advice!

Day -1 | today | +1 | +2 **Aggregation** mean | max



Increased health risk from current air pollution and and preventive measures for at risk population
(Children under 15, adults over 65 and people with pre-existing conditions / suffering from chronic cardio-vascular or respiratory diseases)

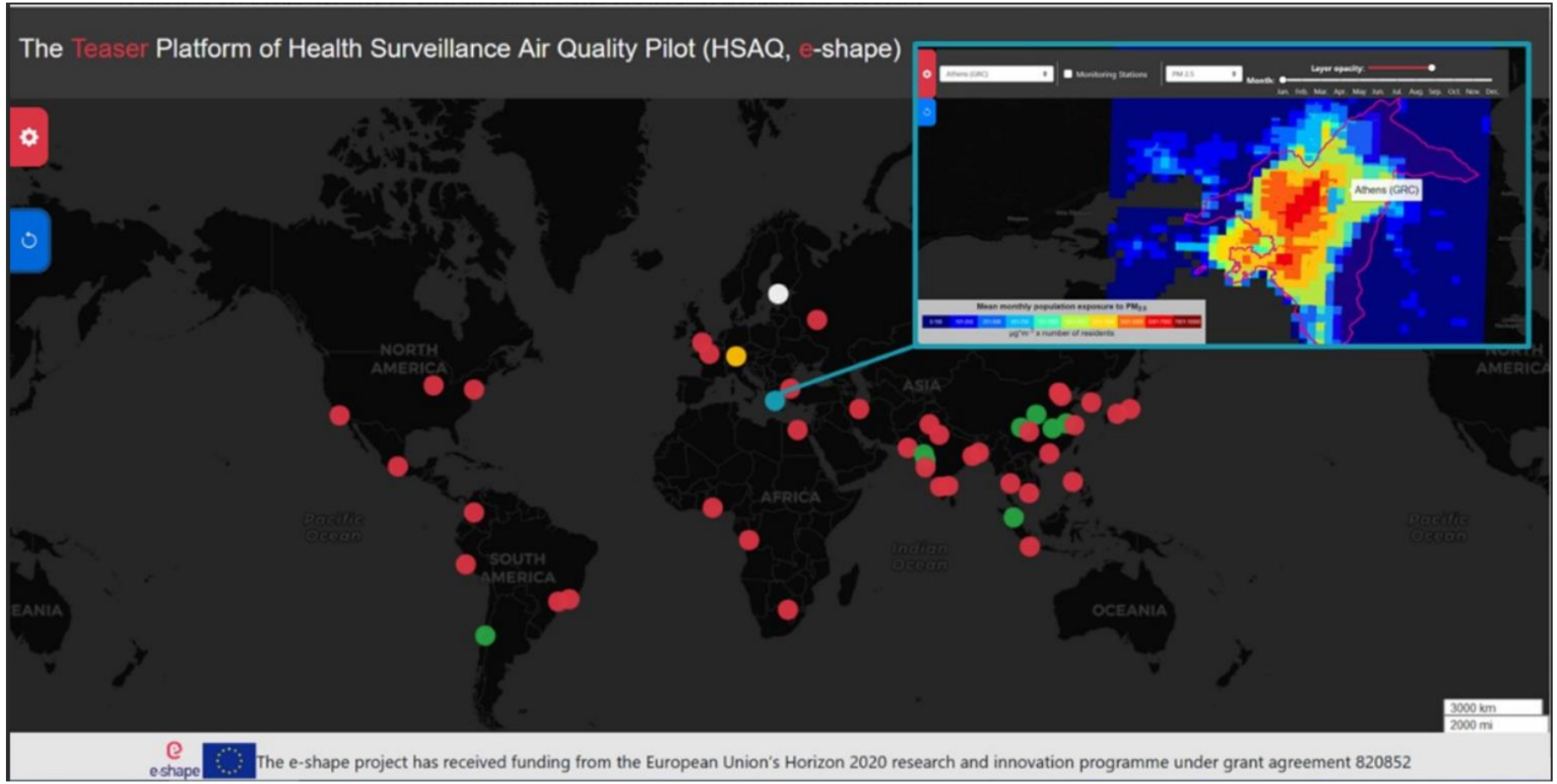
ARI	Increased health risk from current air pollution	Health advice and preventive measures
0	low	Enjoy your usual outdoor activities. Follow your doctor's advice for exercise.
1		
2		
3	moderate	If you have heart or lung problems, consider reducing strenuous physical outdoors activities, or reschedule to times when the index is lower. Follow your doctor's advice for exercise.
4		
5		
6	high	Children, the elderly and people with heart or lungs problems should reduce physical exertion outdoors and particularly if they experience symptoms or reschedule to periods when the index is lower. Follow your doctor's usual advice. People with asthma may find they need to use their reliever inhaler more often. If symptoms persist seek medical advice.
7		
8		
9	very high	Health warnings of emergency conditions! Children, the elderly and people with heart or breathing problems should avoid physical activities. People with asthma may find they need to use their reliever inhaler more often. If you feel uncomfortable, contact your doctor or general practitioner.
10		

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)



Plattorm 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.

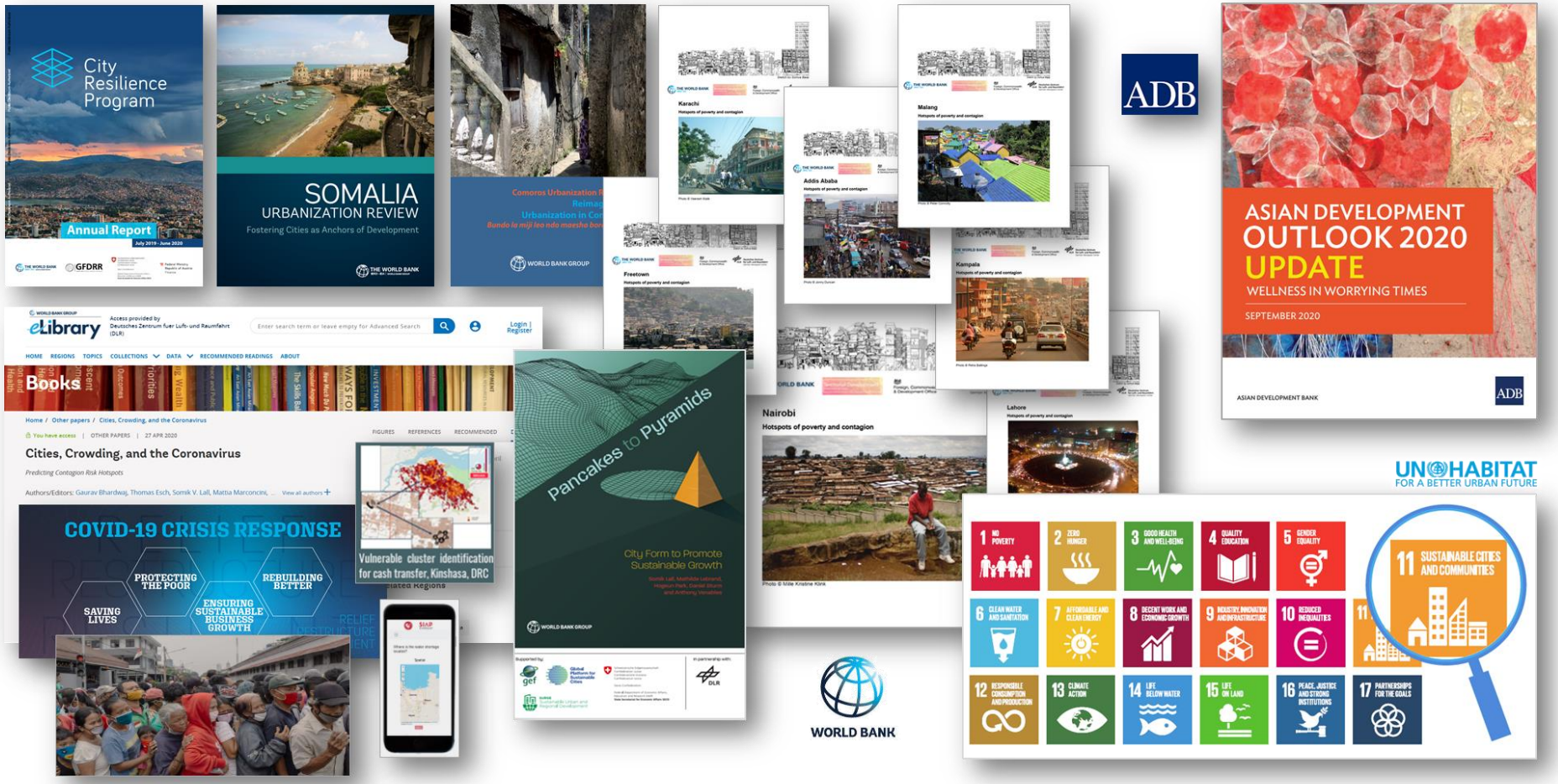
→ Strong need for integrated assessments of climate change and health risks in urban areas

→ 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

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We look forward to contributing to GEO and EuroGEO

Thank you!

Disclaimer

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