



URBAN INSIGHTS FROM SPACE

16th September 2024

Inge Jonckheere

*Head of the Green Solutions Division
European Space Agency*

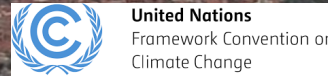
ESA UNCLASSIFIED - For ESA Official Use Only



→ THE EUROPEAN SPACE AGENCY

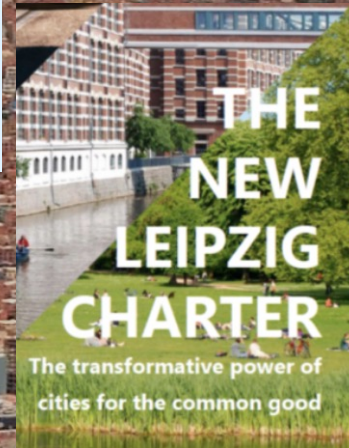
Urban Policies at a Glance

International



Sendai Framework for Disaster Risk Reduction 2015 - 2030			
SENDAI FRAMEWORK	Scope and Purpose	1 Global Outcome	1 Goal
7 Global Targets	13 Guiding Principles		
4 Priorities for Action	at 4 Levels Local, National, Regional and Global		
Role of Stakeholders	International Cooperation and Global Partnerships		

European



National, Regional, Local



Advent of steady satellite data streams

>20 TB per day



Mobilise the data revolution

Data are the foundation of urban development policies and program implementation

Building on ICT advances

High Performance Computing Infrastructures



Sentinel Core Missions

- sentinel-1**
→ RADAR VISION
- sentinel-2**
→ COLOUR VISION
- sentinel-3**
→ A BIGGER PICTURE
- sentinel-4**
→ EUROPEAN AIR MONITORING
- sentinel-sp | sentinel-5**
→ GLOBAL AIR MONITORING
- sentinel-6**
→ SURFING THE SEAS

Sentinel Expansion Missions

- CHIME
- ROSE-L
- CIMR
- CRISTAL
- C02M
- LSTM
- Food Security and Water Management
- Monitoring Land and Natural Resources
- Safeguarding the Arctic
- Combating Climate Change

THE EUROPEAN COPERNICUS PROGRAMME



The European Copernicus Programme



**State-of-the-art
observations with
unprecedented coverage**

sentinel-1

→ RADAR VISION



Systematic data availability

sentinel-2

→ COLOUR VISION



**Full, free and open data
policy**

sentinel-3

→ A BIGGER PICTURE



Long-term availability

sentinel-4

→ EUROPEAN AIR MONITORING



sentinel-sp | sentinel-5

→ GLOBAL AIR MONITORING



sentinel-6

→ SURFING THE SEAS



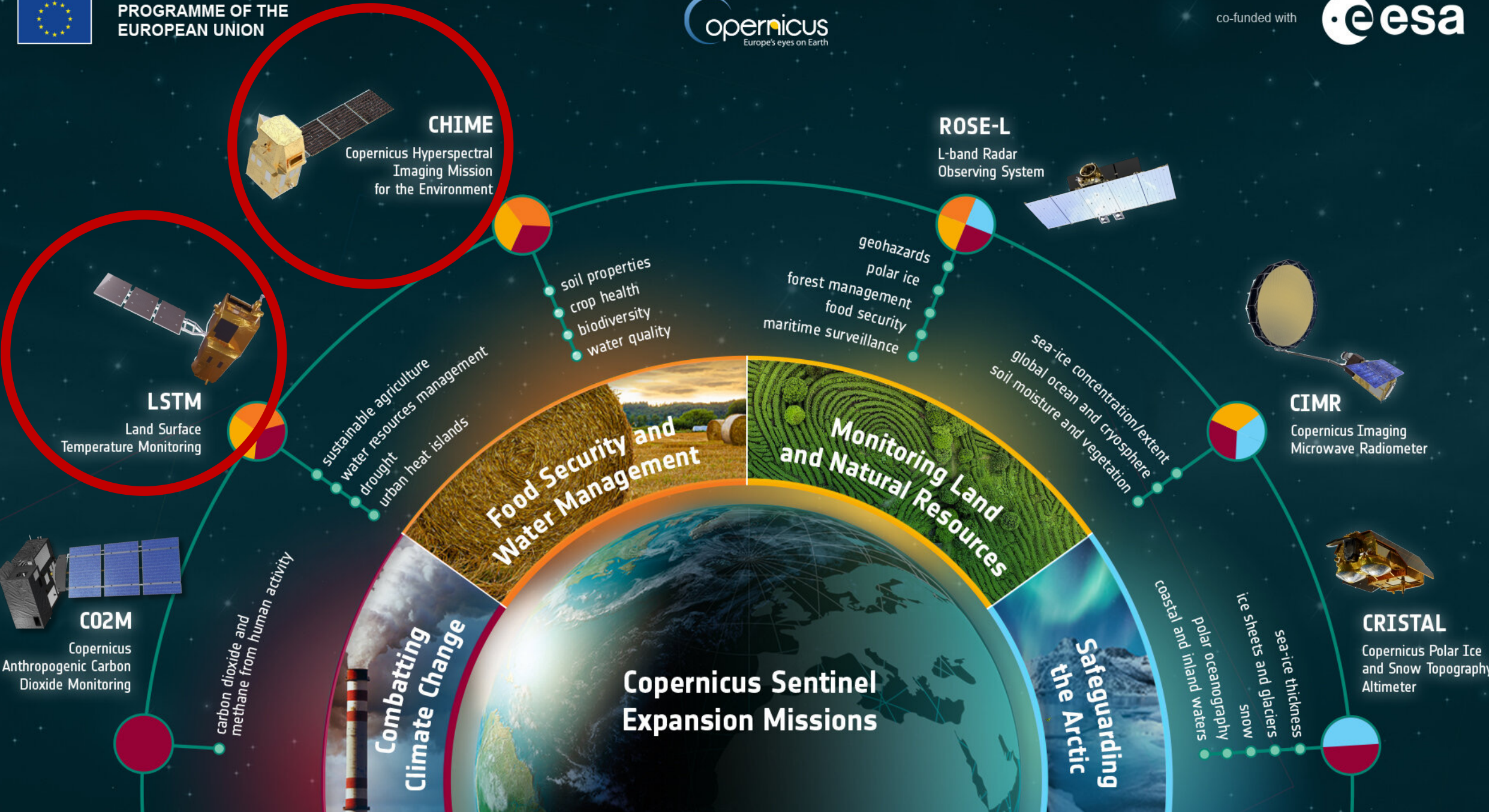
→ Know more: <https://copernicus.eu> and <https://sentinels.copernicus.eu>



PROGRAMME OF THE EUROPEAN UNION



co-funded with



Commercial EO data for urban monitoring



Piazza del Popolo, Rome, Italy
Pleiades Neo © AIRBUS

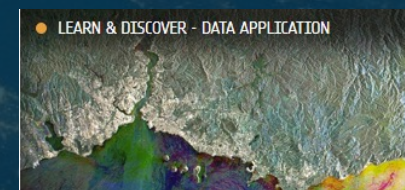


Potsdamer Platz, Berlin, Germany
ICEYE SLEA resolution © ICEYE

Commercial data providers under contract with ESA deliver very high resolution (VHR) optical, SAR and thermal data that offer a unique view of urban settlements. These data are a vital tool to support planning decisions that mitigate challenges like **urban pollution detection, sustainability and development, mapping, heat maps, hazards and risk detection, flood extend monitoring** among others.

- Vision 1
- WorldView
- ICEYE
- PlanetScope
- SkySat
- Pleiades/PNEO
- PAZ
- CosmoSkyMed
- GEOSAT-2
- TerraSAR-X/TanDEM-X
- SatVu
- GHGSat

➔ Since 2022, more than 50 research projects in the urban monitoring domain have been sponsored with commercial data as part of ESA's Third Party Missions (TPM) Program.

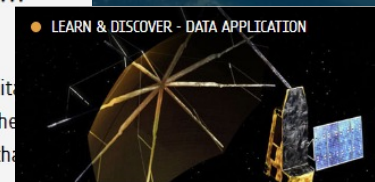


HOW SATELLITE DATA EMPOWER SUSTAINABLE URBAN GROWTH

25 May 2023

observation is a vital tool for facilitating the sustainable development of the world's cities, helping to ensure that

Discover more at:
<https://earth.esa.int/eogateway>



HOW SATELLITE DATA HELP TO SHAPE SOCIETY

29 Sept 2022

this information to work across society, promoting food security, the responsible use of natural resources, sustainable...

About THIRD PARTY MISSIONS PROGRAMME



What are TPMs?

Third Party Missions are earth observation missions that are not owned or operated by ESA. The agency has an agreement with these third parties to distribute data products from their missions to scientific users

History?

ESA's TPM arrangement has been operating for over

45 YEARS

providing EO data to users in Europe and worldwide for research and pre-operational applications development

How many?

TPMs currently include over 60 instruments on more than 50 missions

<60 **50+**
INSTRUMENTS MISSIONS



ESA Third Party Missions
Free commercial data for research and applications development

How?

TPM datasets are distributed under specific agreements with the owners or operators of the mission – some sets are available under the free dataset policy, requiring only a fast registration, others are part of a restrained data set and require the submission of a project proposal or service request

- Data provision from over 50 TPMs with inclusion of an ever-growing number of new commercial Very High Resolution and NewSpace missions/constellations.
- Full/partial operations support for a subset of scientific public TPMs.
- Data quality benchmarks and assessments for commercial and NewSpace missions.

Innovation?

IN 2018

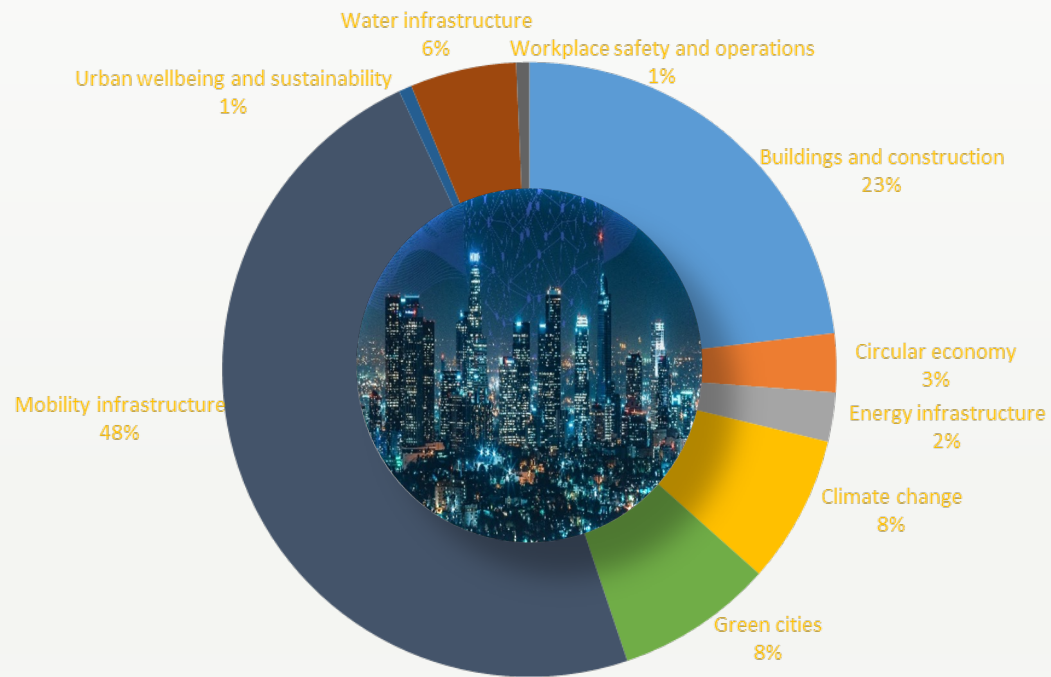
ESA changed the agreements with the commercial TPM data providers in order to also include start-ups and entrepreneurs in incubators, to access the data. This greatly supports ESA's Technology Transfer Programme Office (TTPO)

Data Access?

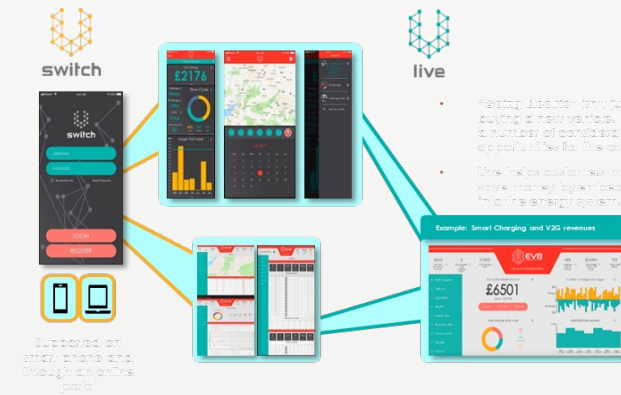
<https://earth.esa.int/eogateway/search?category=Data>

Space at the service of Smart and Green Cities

Market demand from smart cities for green solutions, new regulations, space opportunities awareness and cross-sector collaboration will support future growth in green and sustainable investment



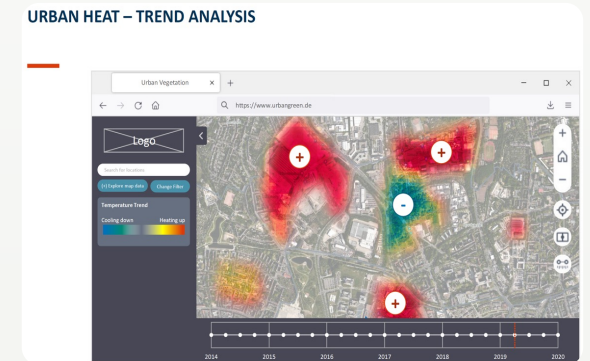
Green cities



Mobility infrastructure



Buildings and accessibility



Climate change

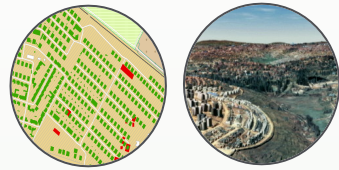
EO for Sustainable and Resilient Cities: standard products



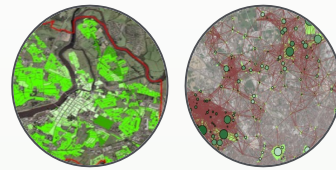
Built-Up Extent, Imperviousness



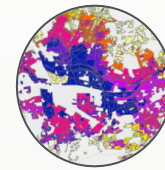
Building Footprints and 3D Models



Green Areas/Networks



Population Density



Transport Infrastructure



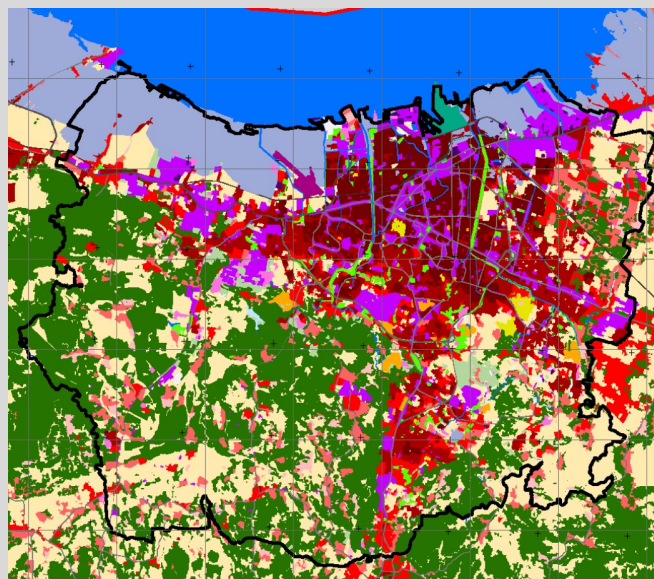
Waste Sites



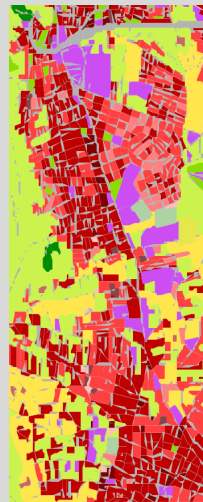
Informal Settlements



Baseline Optical Products
Urban and Peri-Urban
Land Use / Land Cover



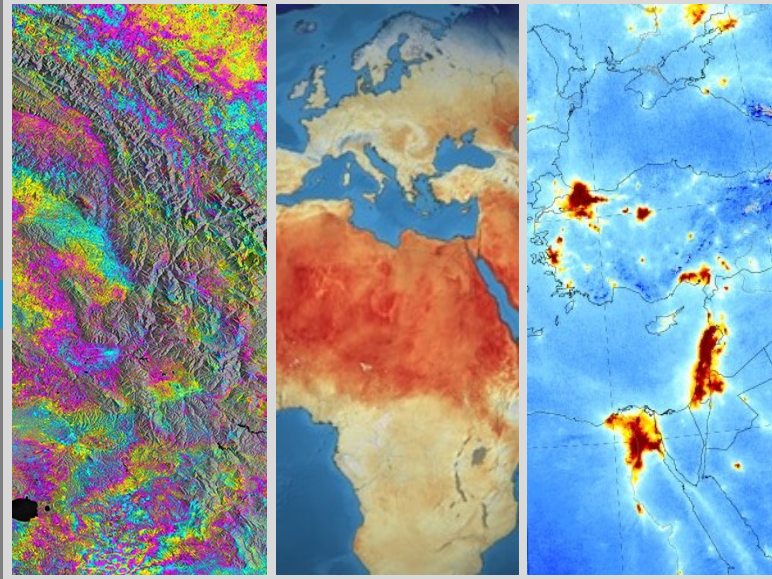
Detailed



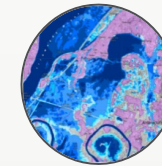
Change



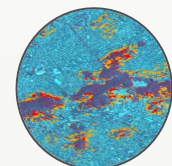
Specialised Observations
Microwave radar, thermal radiometry,
tropospheric spectrometry



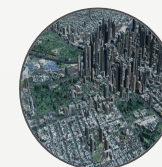
Flood Risk



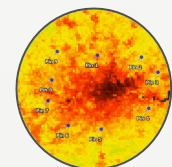
Landslide Risk



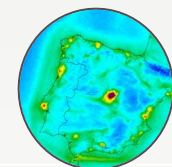
Terrain Motion



Urban Heat Islands



Air Quality



From Use Case to EO-based Product Development



Use Cases



Land and Growth



Buildings



Deprivation



NBS



Liveability



Transport



Master Planning



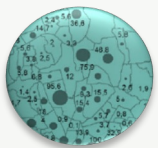
Socio-economic

EO-Derived Input Data

Non-EO Input Data



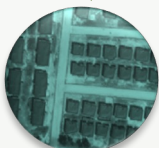
LULC/Imperviousness/Transport



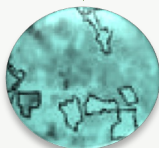
Open Green Areas



Population/Informal Settlements



Buildings



Waste/Air/UHI



Hazards



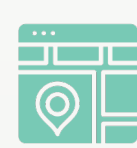
Census Data



Administrative



Municipal Dashboards



Attractors/PoIs



Sensor Data



Economic Projections

...

Information Product / Service Development

User-tailored geospatial data products

Enhanced Production and Service Modality (automatic/cloud/AI)

User-Focused Analytics (GIS, interactive, indicators, dashboards)

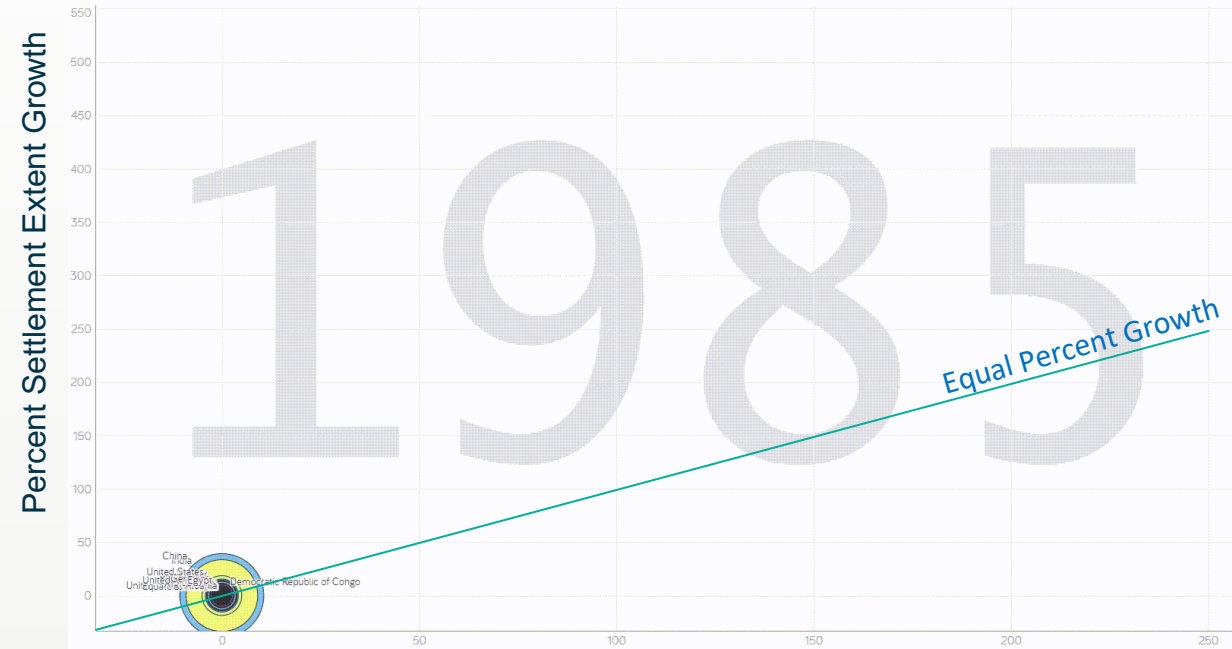
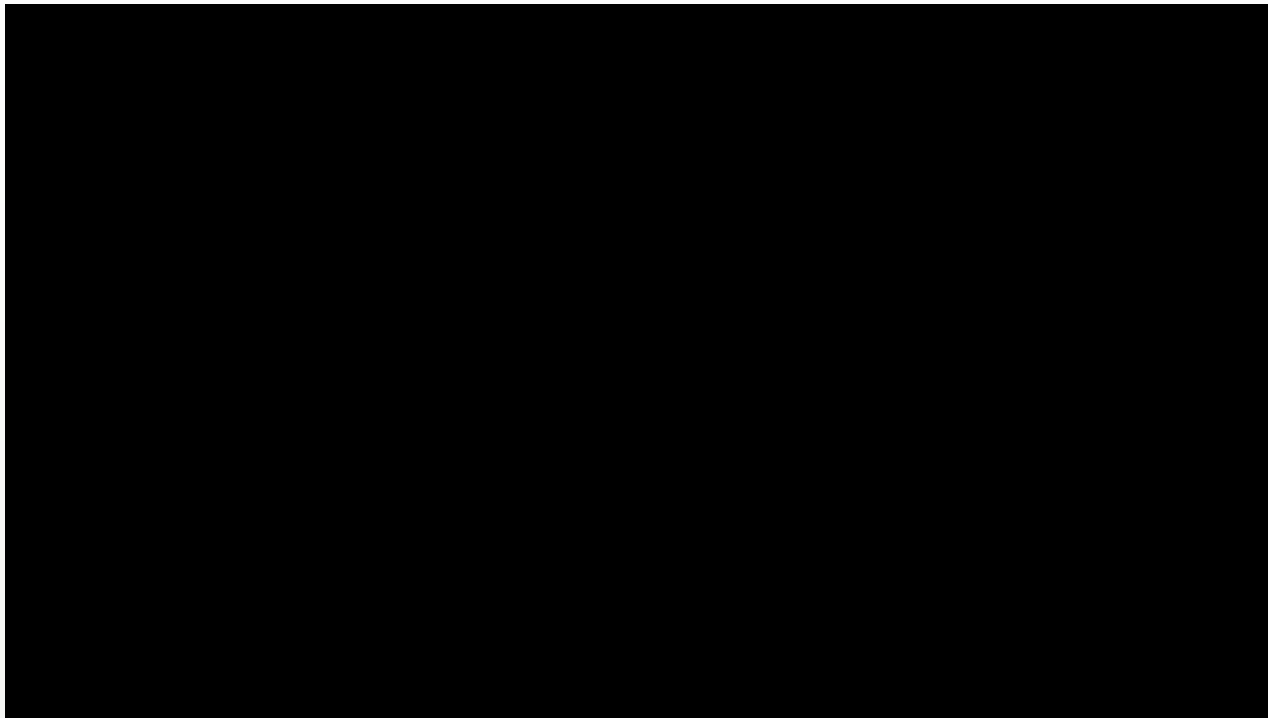
Backcasting -> Nowcasting -> Forecasting Modelling

Project-specific (e.g. city-scale -> quadrant/neighb.)

Innovative Products



Monitoring and understanding Urban Growth dynamics



WSF 2015

S1 and Landsat 8
10m
Released
in June 2019

**WSF Evolution
1985-2015**

Landsat
30m
Released
in Nov 2021

WSF 2019

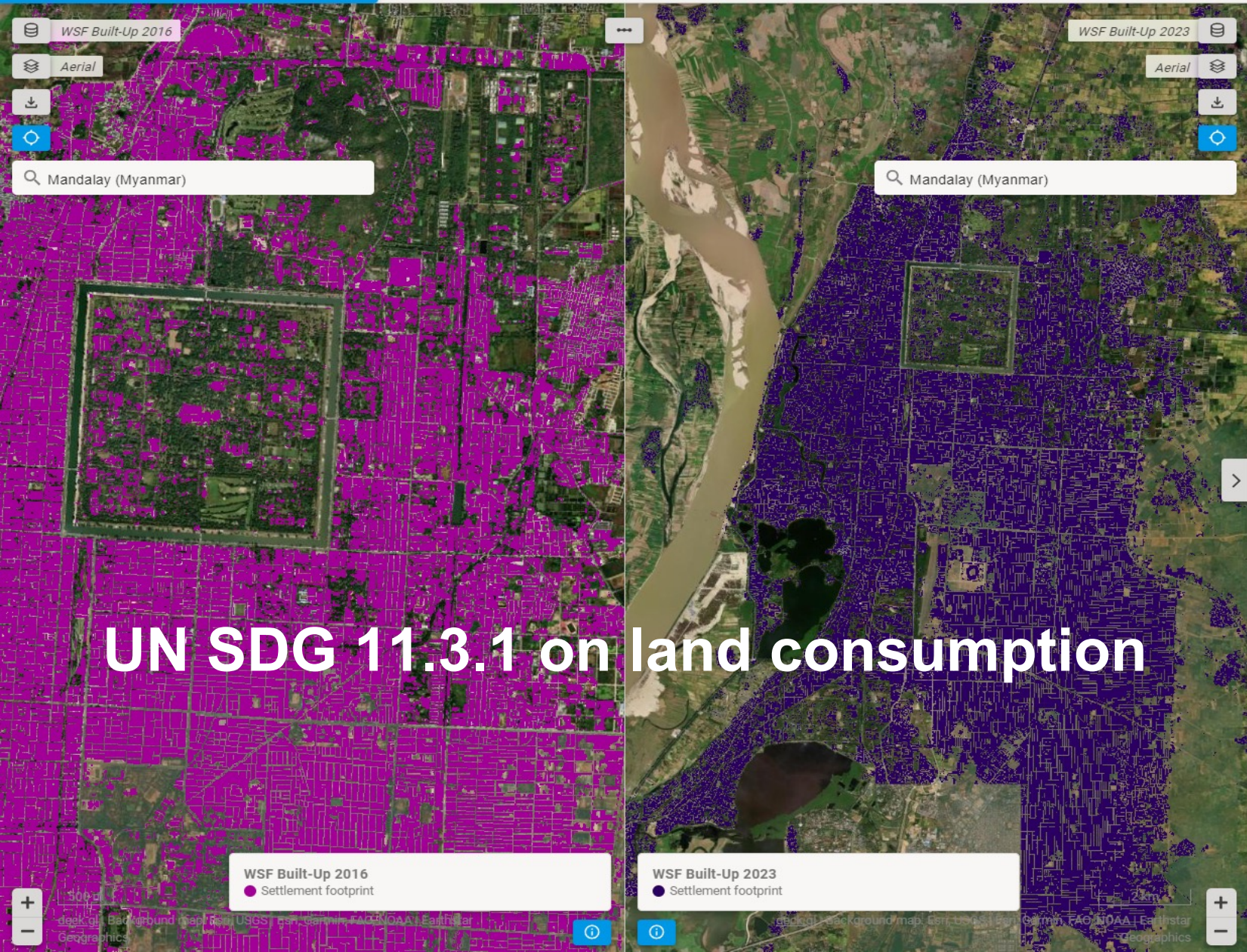
S1 and S2
10m
Released
in Nov 2021



Percent Population Growth

- Europe & Central Asia
- East Asia & Pacific
- South Asia
- North America
- Latin America & Caribbean
- Middle East & North Africa
- Sub-Saharan Africa





Benchmark type: **Areas** Datasets Area type: **Regions** City clusters

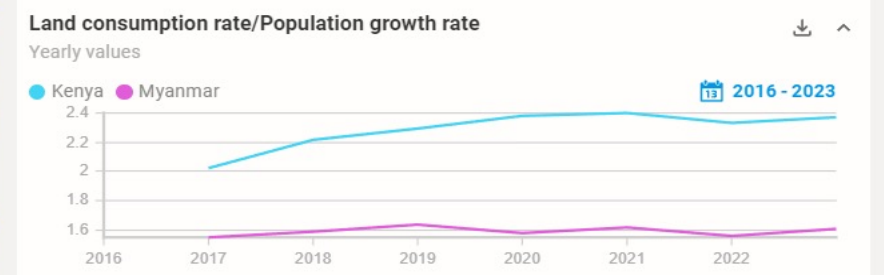
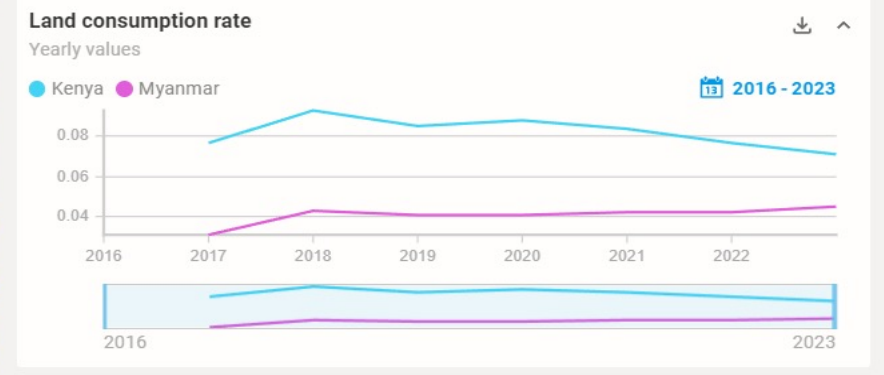
Areas: **Kenya** **Myanmar**

Datasets: **WSF 16-23 Built-up (10m)** Partial Land

Period: 2016 **16** **23** 2023

SDG Indicators

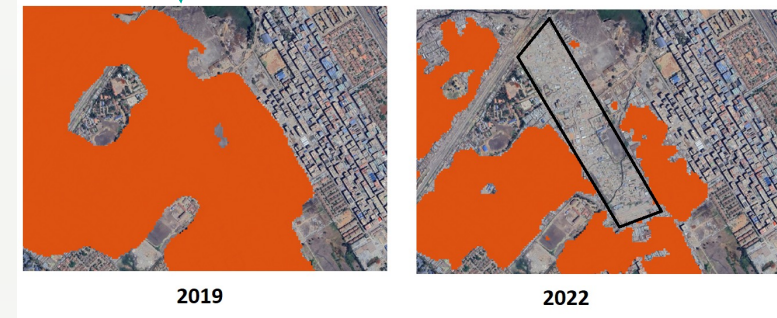
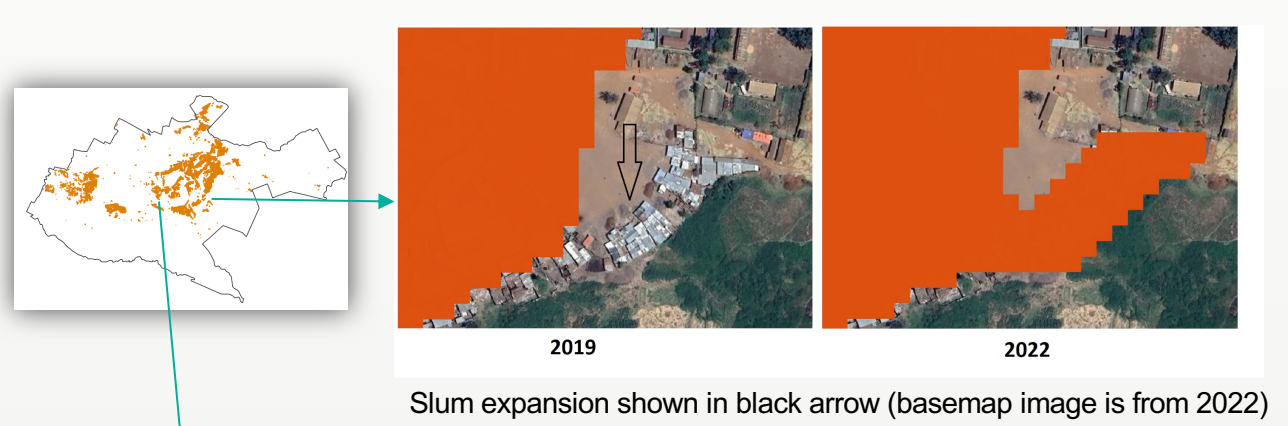
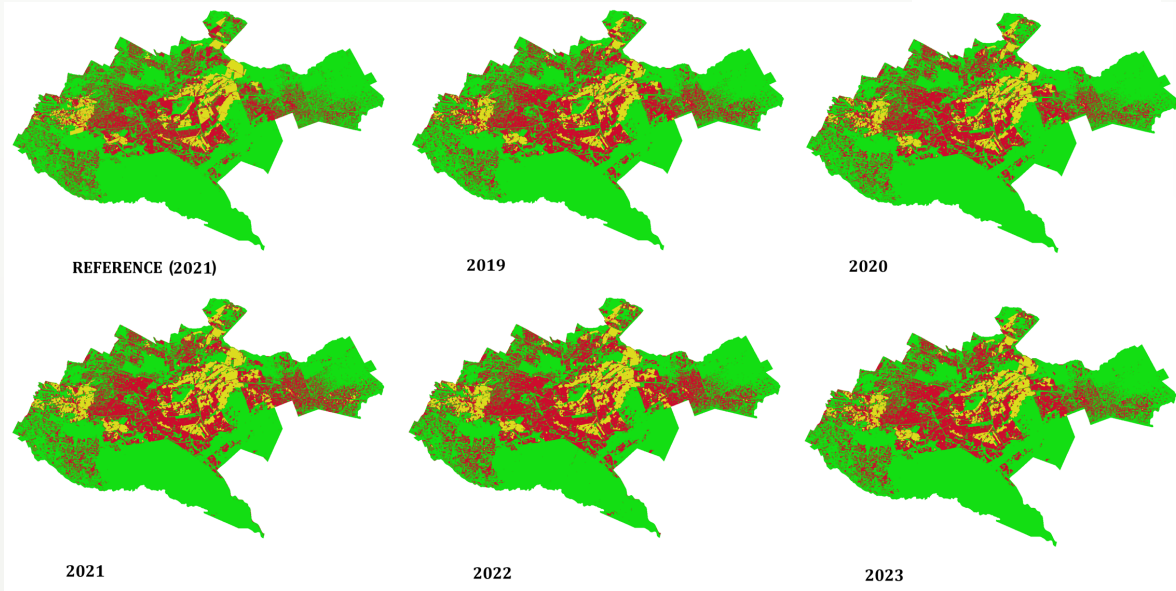
Indicator	Period	Rate
Land consumption rate	2016-2023	0.071
	2016-2023	0.045
Land Consumption Rate/Population Growth Rate	2016-2023	2.356
	2016-2023	1.613
Land Consumption per capita	2016-2023	64.711 sqm/inh.
	2016-2023	48.609 sqm/inh.





Multi-temporal Analysis – Nairobi

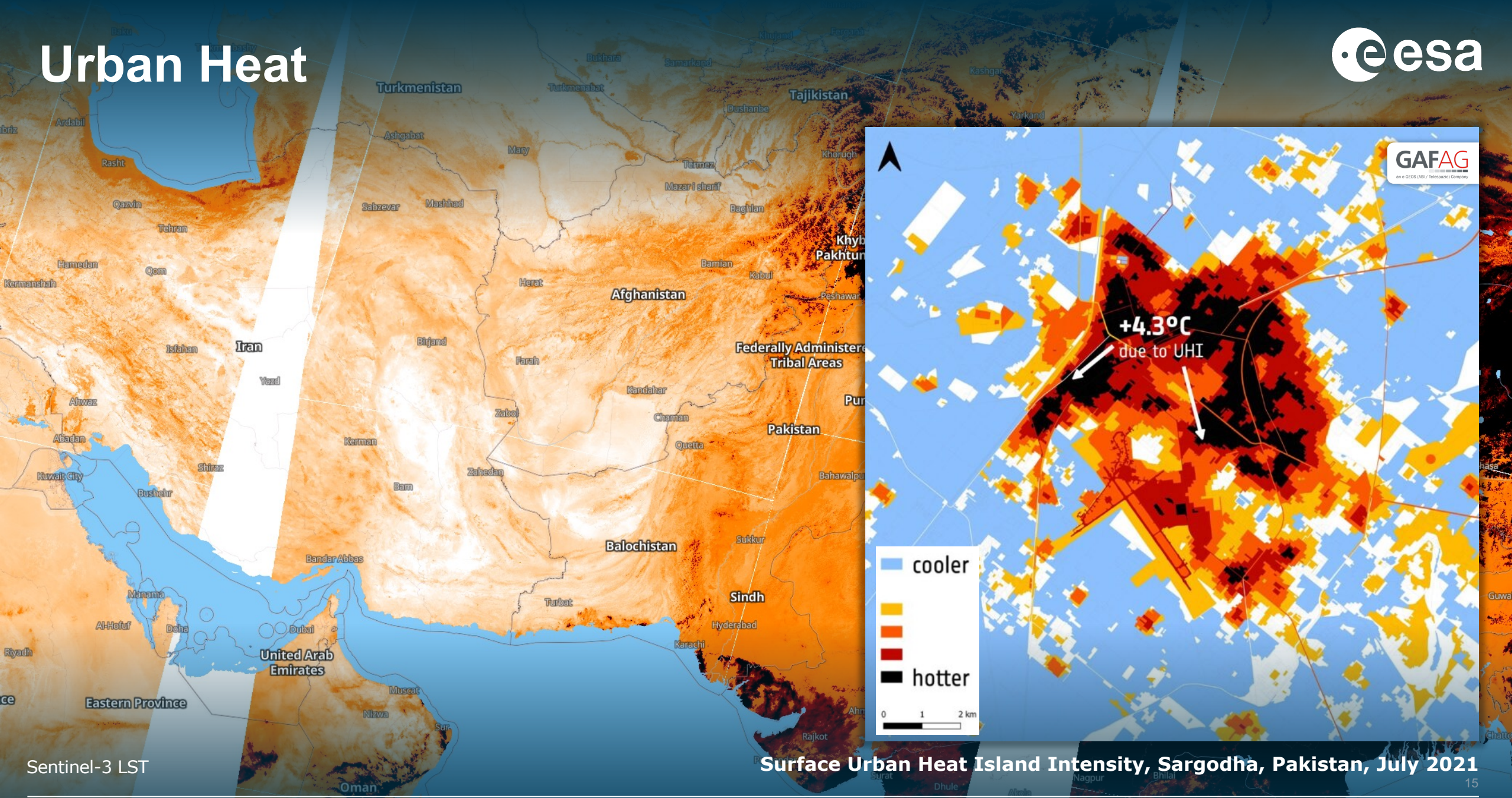
Spatio-temporal transferability (2019-23)



The orange polygons indicate the slum extents predicted by the AI model for two different years within the same area

Demolished slum in Mukuru (shown in a rectangle outline)

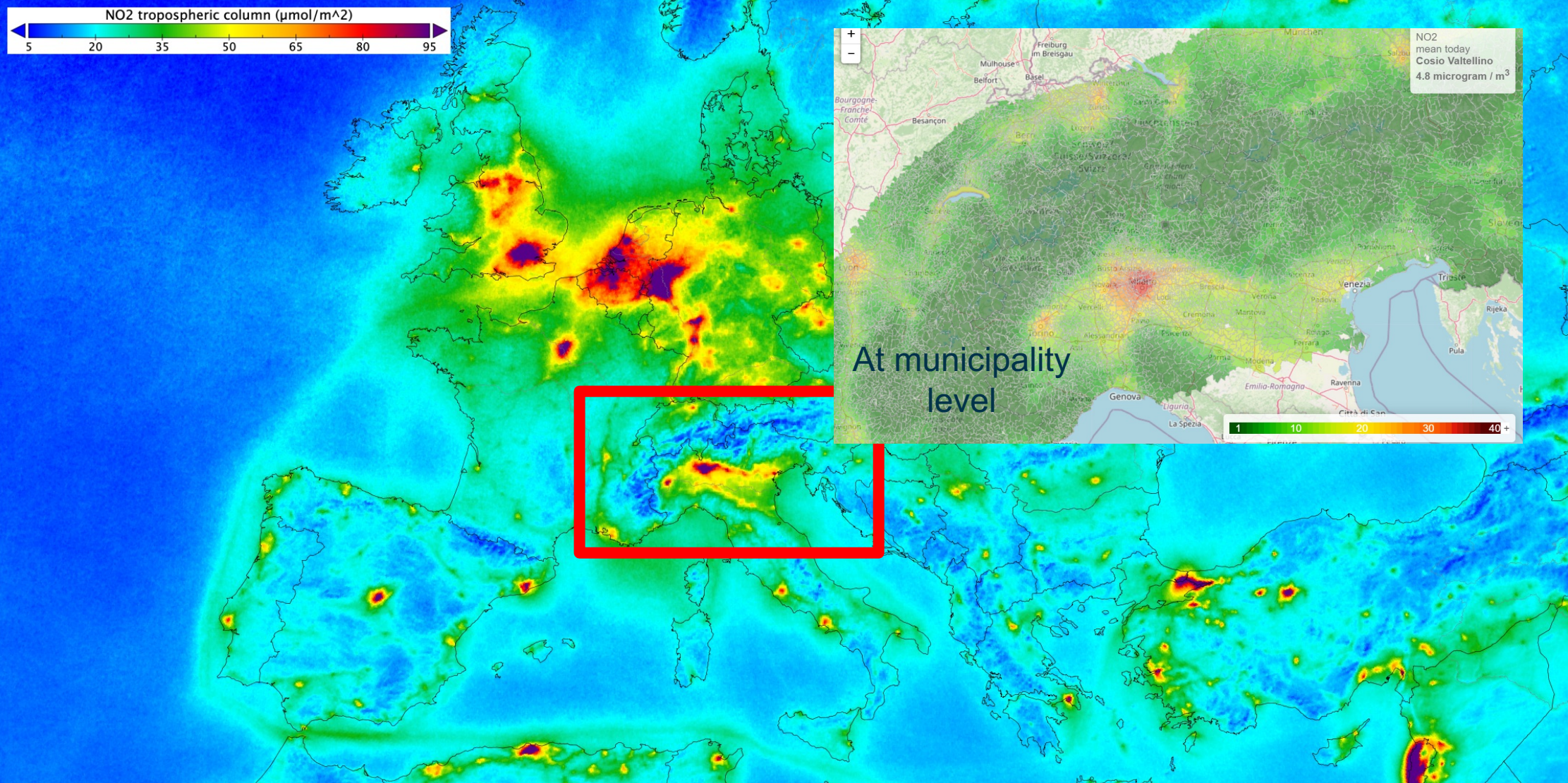
Urban Heat



Sentinel-3 LST

Surface Urban Heat Island Intensity, Sargodha, Pakistan, July 2021

Air Quality



urban tep | Data exploration | Portal | Support (Redmine) | Video Help | Felix.Bachofer

Place: Oslo | Theme: City characteristics | Periods: 2019 | Visualization: Land cover - overview

Layers | Areas | Selections | Areas filter | Map tools | Add layer | Snapshots | Views

Layers

- Analytical Units Layers
 - Area outlines
- Info Layers
 - Land Cover Land Use
 - Land use / Land Cover - Sentin...
 - Urban Green
 - Urban greenery - Tree crown
 - Urban greenery - Green view in...
- Background layers

Structure of Land cover (% of AU area) [%]

Alna, Bjerke, Frogner, Gamle Oslo, Grorud, Grünerlokk, Nordre Ake, Nordstrand, Ostensjo, Sagene, Sentrum, Sondre Nor, St. Hansha, Stovner, Ullern

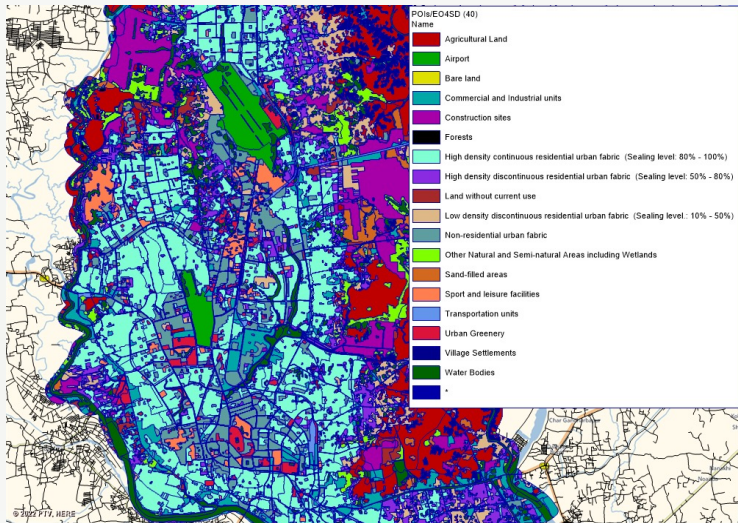
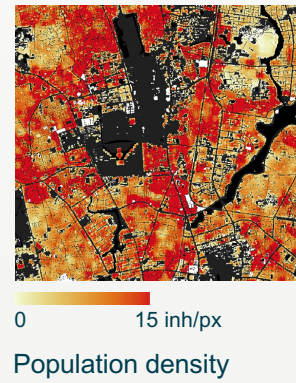
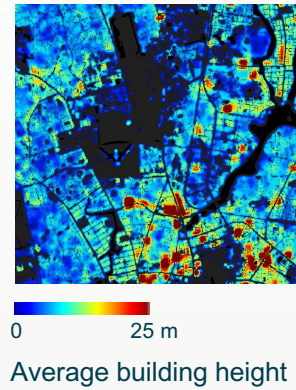
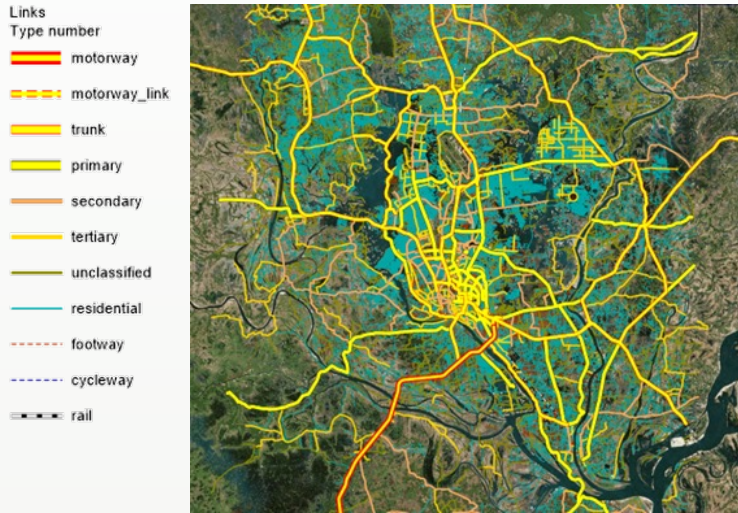
Summary of Land cover [ha]

Name	Agriculture / low veget...	Open land (2019)	Built-up Area (20...
Alna	11.31	28.53	764.5

Green Urban Areas Inventory, Oslo, Norway

Transport and Mobility Planning

EO inputs



Macroscopic Transport Model for Dhaka, Bangladesh



Transport and maintenance planning

Outputs:

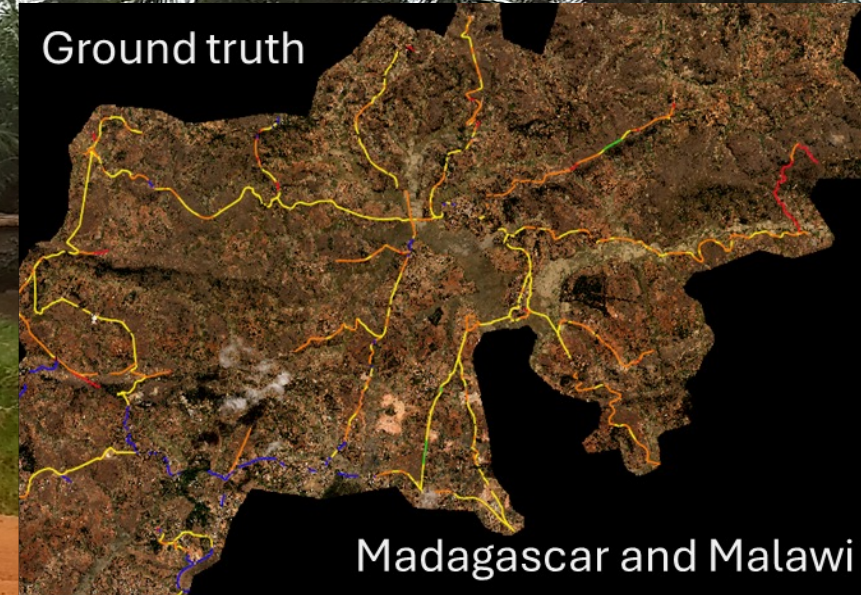
Trials of different resolutions

QGIS Plug-in

Machine learning models blended for best results

Cost Benefit Analysis

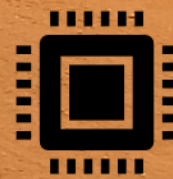
Roadmap for further development



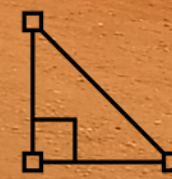
Define requirements



Acquire imagery



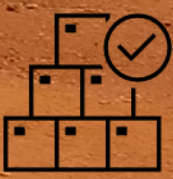
Clean data



Calibration, ground truth



Apply ML model

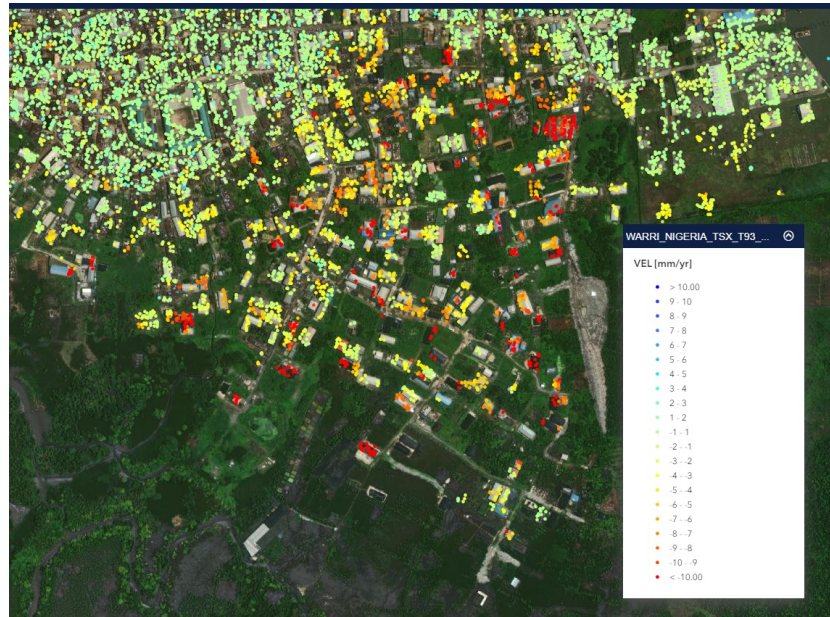


Condition analysis

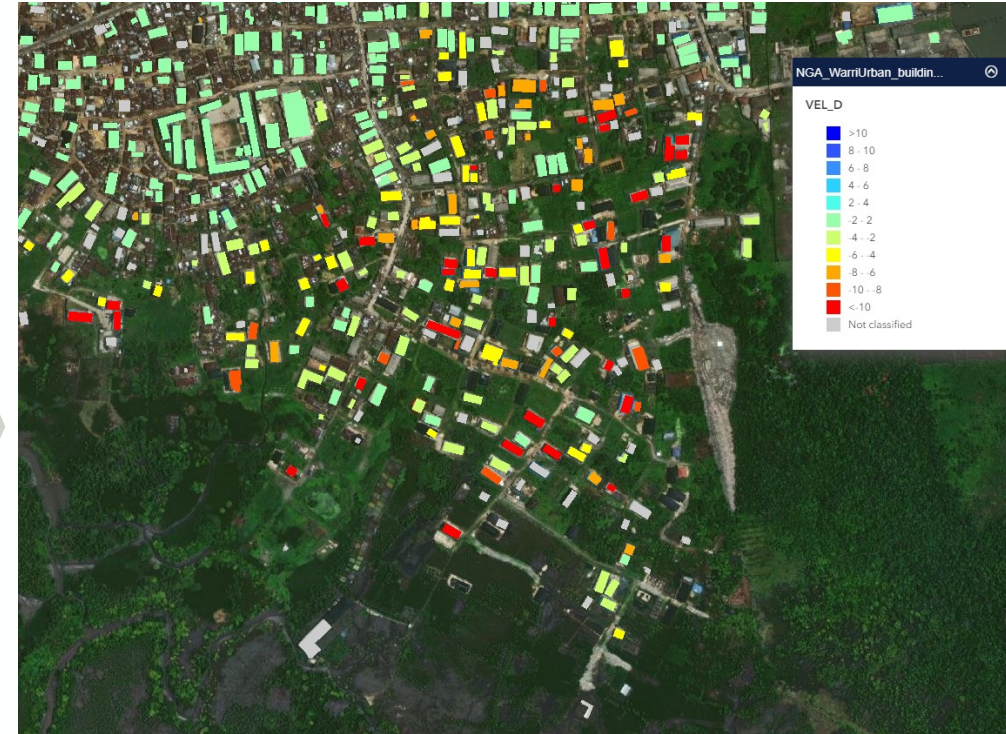
Ground Motion / Subsidence



Building footprints layer



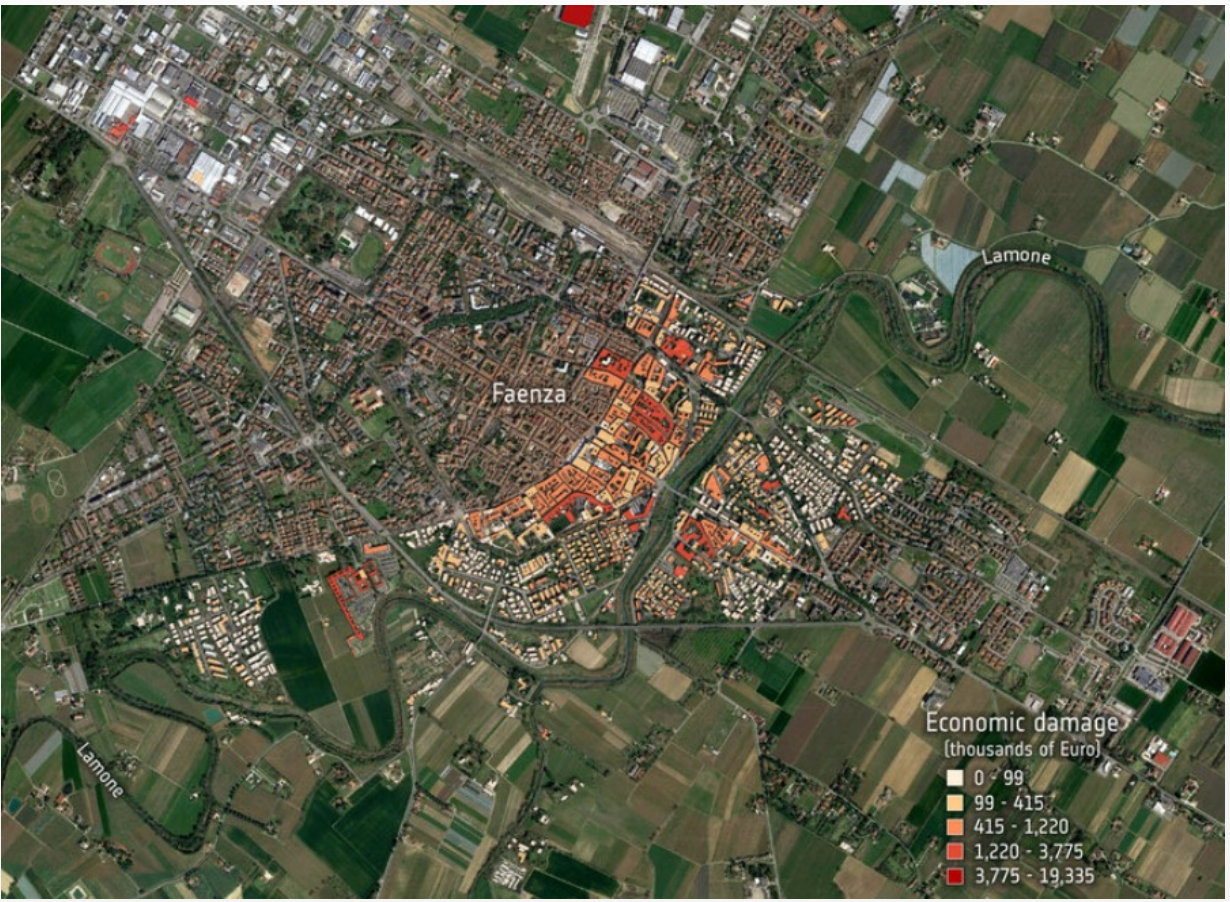
Ground displacement map
(TerraSAR-X descending pass,
April 2018 to July 2022)



Intervention priority levels based on ground displacement



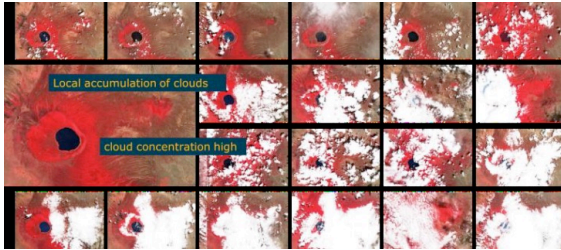
Urban Floods



Energy Transition and Renewables: Solar

National, regional and local/rooftop solar potential, Armenia

Cloud cover statistics



Solar potential

Land use & land cover



Building/rooftop extraction

Rooftop solar potential



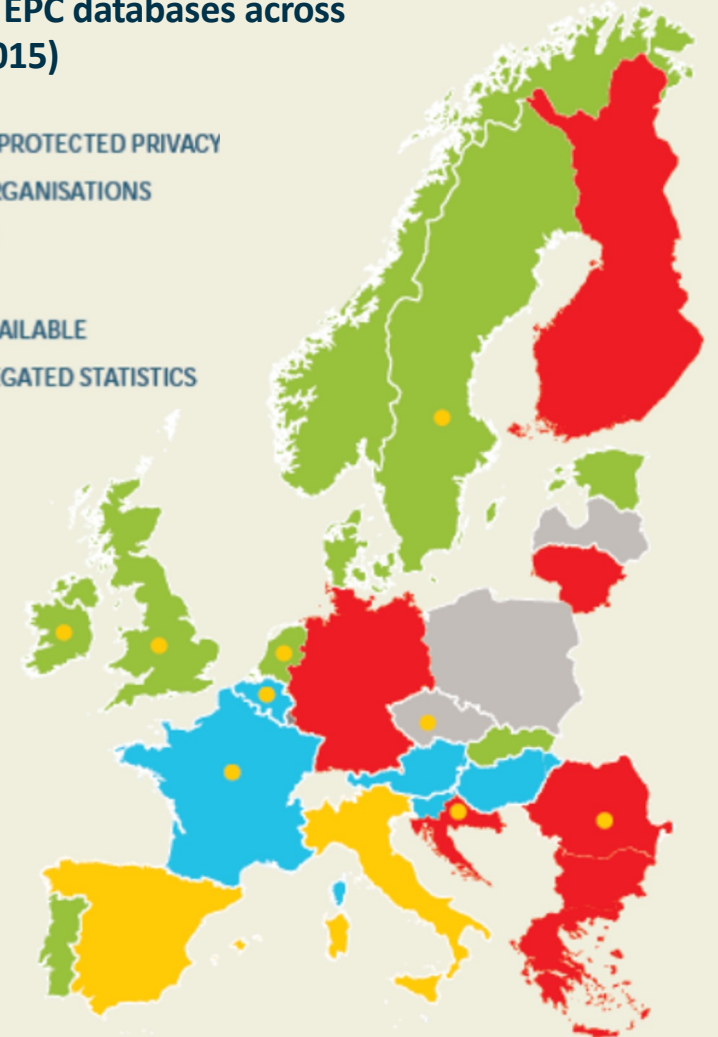
Limitations of EPC Databases for Urban Planning

- Data Gaps and Incompleteness
- Lack of Standardisation
- Coverage Limitation
- Limited Public Access
- Highly labour intensive
- Lack of Update and Maintenance

Score	Energy rating	Current	Potential
92+	A		
81-91	B		
69-80	C	80 C	80 C
55-68	D		
39-54	E		
21-38	F		
1-20	G		

Public access to EPC databases across Europe (BPIE, 2015)

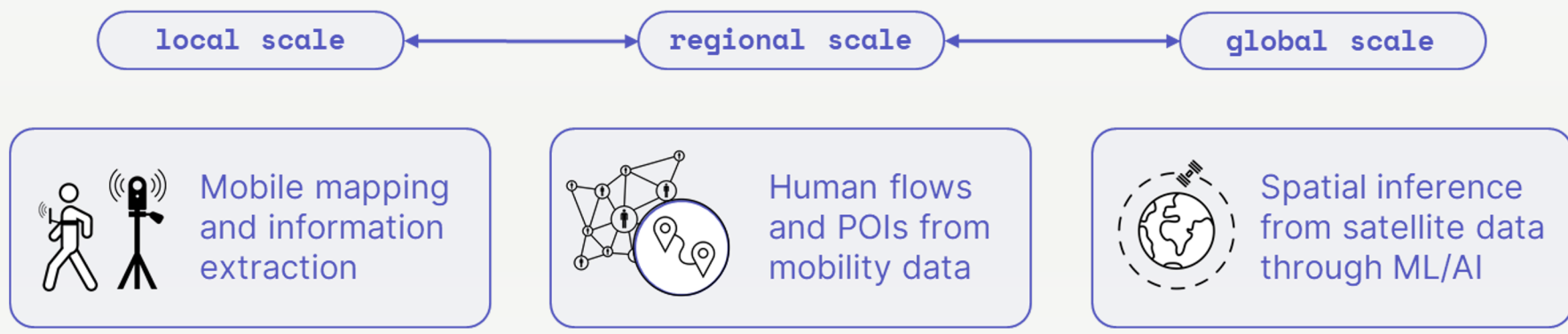
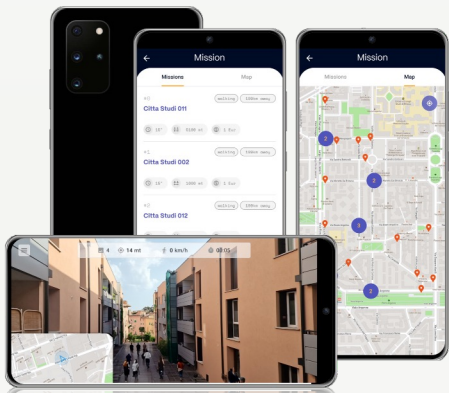
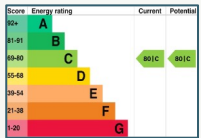
- PUBLIC ACCESS WITH PROTECTED PRIVACY
- ACCESS FOR SOME ORGANISATIONS
- DEPENDS ON REGION
- NO PUBLIC ACCESS
- EPC REGISTER NOT AVAILABLE
- PROVISION OF AGGREGATED STATISTICS



Energy Efficiency Estimation with AI

WHAT: Assessing buildings' energy performance and retrofitting potential by jointly leveraging Earth Observation and in-situ data.

HOW: Design, implement, and validate a multi-modal AI-based system able to automatically estimate the energy efficiency level of single buildings, ranking them from "A" (most energy-efficient) to "G" (least energy-efficient) and to generate recommendations for interventions.



Urban Morphometric Changes

EuroFAB – Europe’s Urban Fabric

WHAT: Assessing urban fabric and urban morphometric change over time by leveraging Earth Observation data.

HOW: Design, implement, and validate an **AI-based system** able to **automatically classify spatiotemporal urban morphometric signatures**, endorsed by national statistical offices and to support spatial development policy of the Check Republic and UK and **generate recommendations for green transition predictive services.**

The Alan Turing Institute

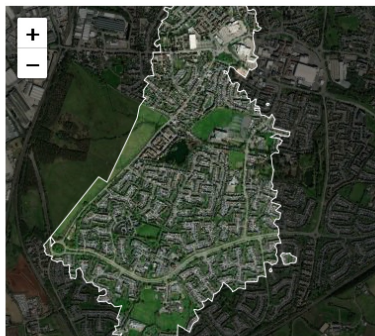


CHARLES UNIVERSITY



Disconnected suburbia

“Disconnected suburbia” includes residential developments in the outskirts of cities or even towns and villages with convoluted, disconnected street networks, low built-up and population densities, and lack of jobs and services. This signature type is entirely car-dependent.



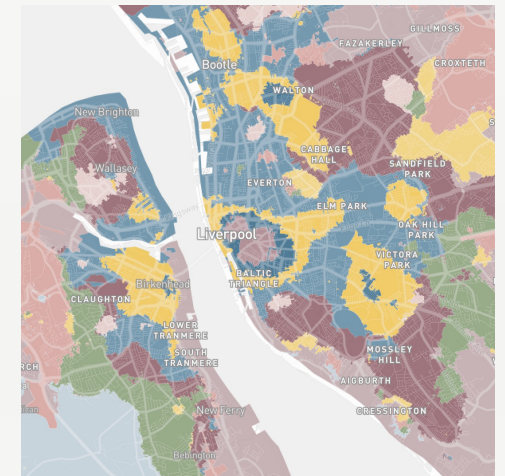
Leaflet | Tiles © Esri — Source: Esri, I-cubed, USDA, USGS, AEX, GeoEye, Getmapping, Aerogrid, IGN, IGP, UPR-EGP, and the GIS User Community, © Martin Fleischmann, Dani Arribas-Bel, Urban Grammar AI research project



Leaflet | Tiles © Esri — Source: Esri, I-cubed, USDA, USGS, AEX, GeoEye, Getmapping, Aerogrid, IGN, IGP, UPR-EGP, and the GIS User Community, © Martin Fleischmann, Dani Arribas-Bel, Urban Grammar AI research project

Hyper concentrated urbanity

The epitome of urbanity in the British context. “Hyper concentrated urbanity” is a signature type present only in the centre of London, around the Soho district, and covering Oxford and Regent streets. This signature is the result of centuries of urban primacy, with a multitude of historical layers interwoven, very high built-up and population density, and extreme abundance of amenities, services and jobs.



Urban Energy Efficiency: ThermCERT



Identify areas across the UK where energy efficiency measures are most needed

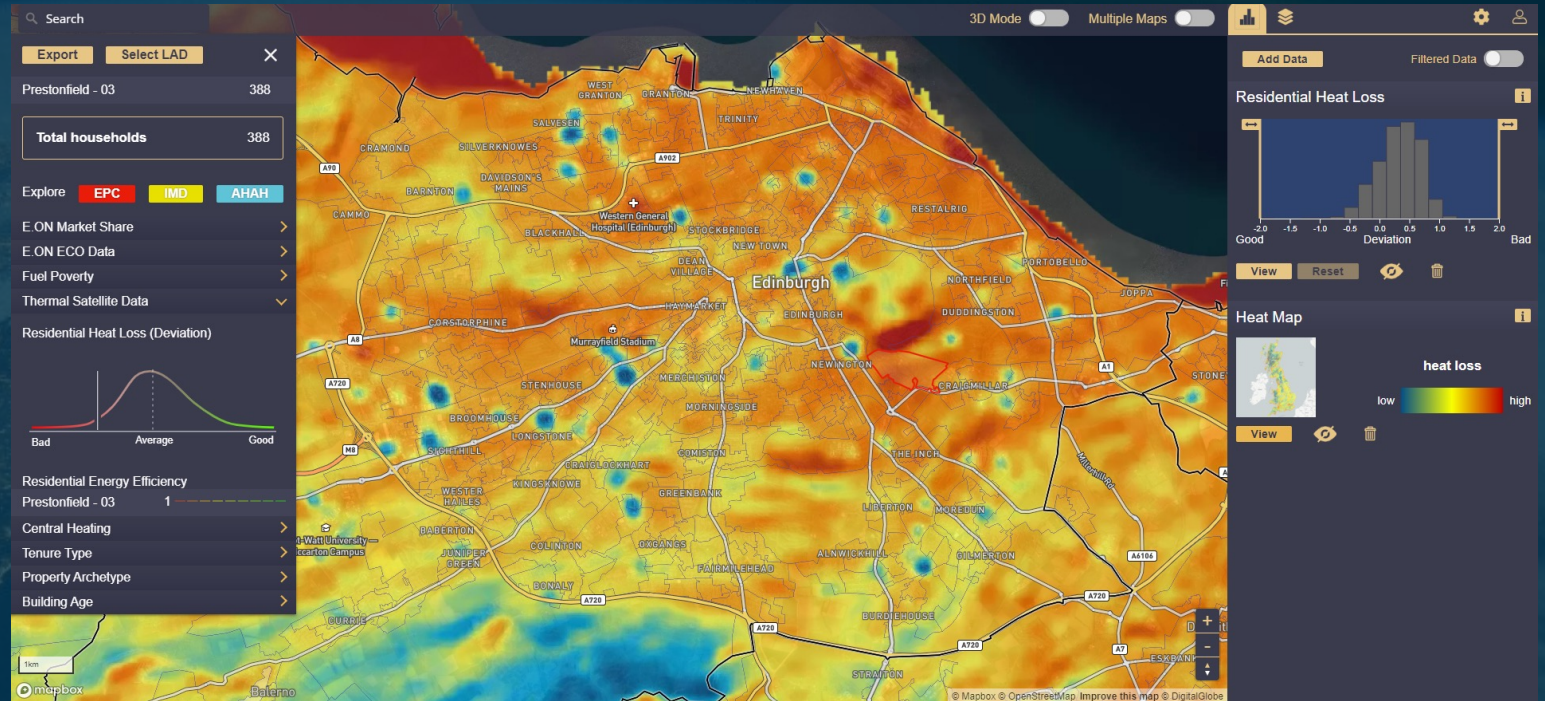


ASTROSAT

Targeted Users:



local authorities



Thermal and optical satellite images, government and national census data to derive Residential Heat Loss, Residential Energy Efficiency, Building Age, and Fuel Poverty Prediction

Publicly available geographic information visualised in simple and effective analysis tool.



Urban Super-Resolution Imagery

The issue:

- Very-High Resolution imagery comes usually at cost and acquired infrequently
- Free and open datasets have lower resolution but available more frequently

Super-Resolution techniques:

- Creation of higher resolution images from lower resolution inputs
- Advanced algorithms, machine learning models, and mathematical optimisations to infer high-frequency details and enhance spatial resolution
- Techniques can be implemented computationally efficiently and scalable, inputs from various satellite platforms and sensors
- Single-Image Super-Resolution (SISR) vs Multi-Image Super-Resolution (MISR)



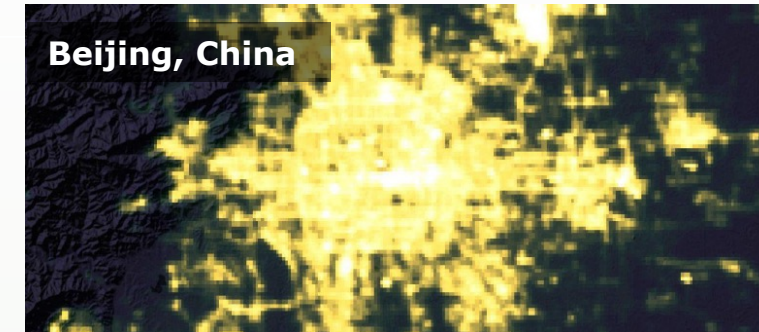
Sentinel-2 original (10 m resolution)



Sentinel-2 Super-Resolved (2.5 m resolution)



building footprints extracted via Neural Networks



VIIRS-DNB Night-Time Lights monthly average (500 m)

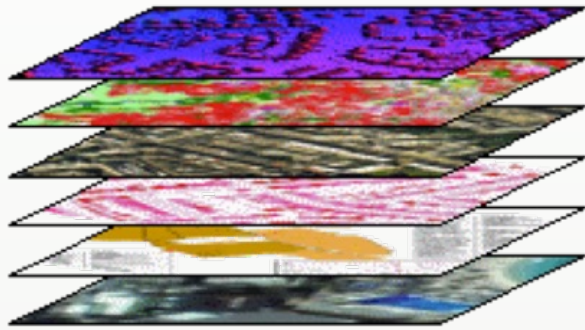


Luojia 1-01 Night-Time Lights (130 m)

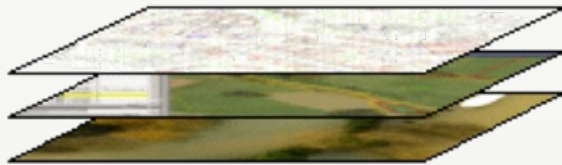


City Data Cubes

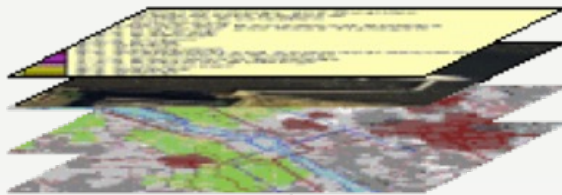
EO data – Sentinels, commercial data, drones, aerial data, ...



Non-EO data: socio-economic, mobility data, ...

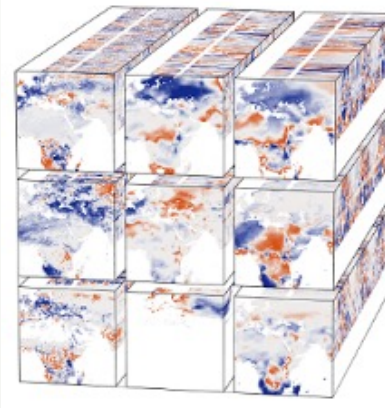


Bring your own data



EURO DATA CUBE

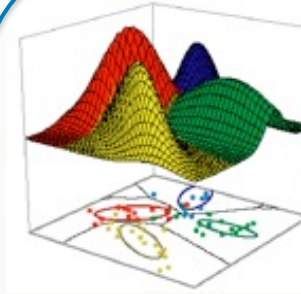
City Data Cubes



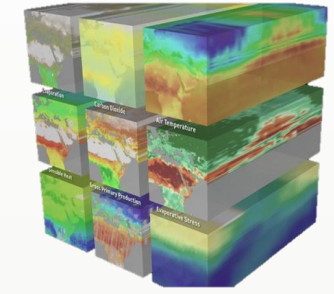
OGC

API

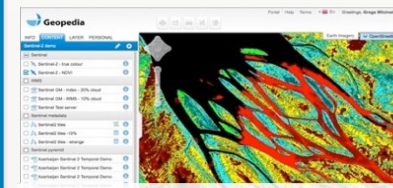
PYTHON



Machine learning



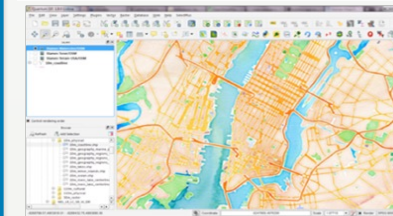
Ad-hoc analysis



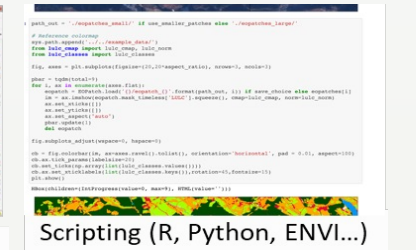
Cloud GIS



Web / Mobile apps



Desktop (QGIS,, ArcGIS...)



Scripting (R, Python, ENVI...)

Applications

Digital Twins of Cities

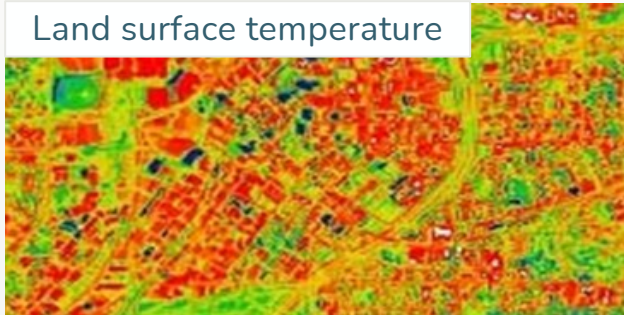


AI4SC Digital Twin Urban Pilot



EO & Ancillary Data Integration

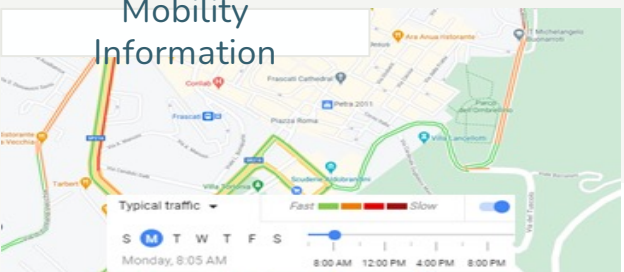
Land surface temperature



Land subsidence



Mobility Information



3D Model Generation and Digital Twin Web Platform



Virtual & Augmented Reality



AI Integration





Thank You!