Potential of Earth Observation to address global challenges of cities

Copernicus for Future cities workshop, 9 November 2018, Brussels
Session III: cities challenges, user needs and innovation paths

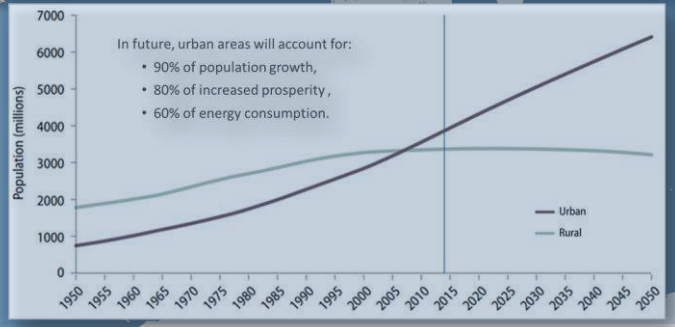
Marc Paganini, Zoltan Bartalis
European Space Agency (ESA), Directorate of Earth Observation Programmes
with the contribution of **T. Esch**, **M. Marconcini** (DLR) and **S. Gomez** (GAF)

Global Urban Agendas

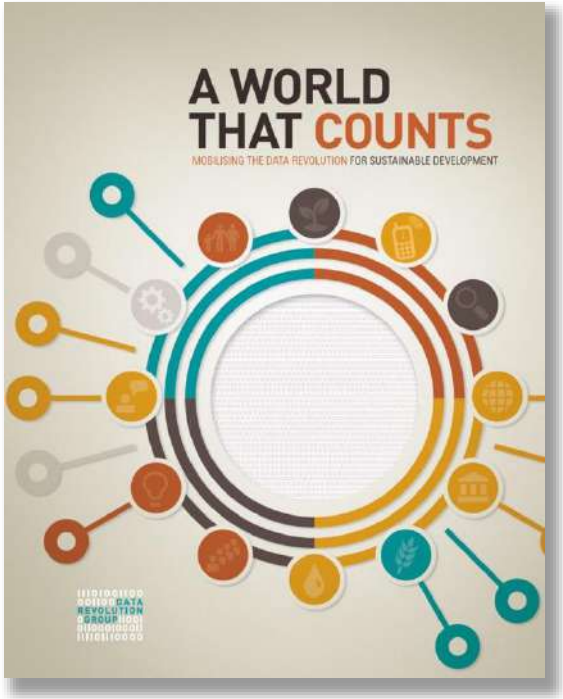
"The scientific and policy communities increasingly recognize that cities […] and the underlying urbanization processes are at the center of global climate change and sustainability challenges.

Policymakers need facts, empirical evidence, and scientifically sound theories on how to plan and manage cities and urbanization…"

Solecki et al. (2013): It's time for an urbanization science. Environment 55(1), pp. 12-16



Mobilizing the Data Revolution for Sustainable Development



UN SG Independent Expert Advisory Group, 11/2014

*"**Data** and **evidence** are the foundation of development policies and effective program implementation."*

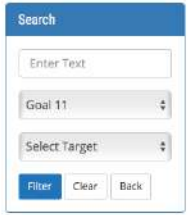
Mahmoud Mohieldin, SVP, World Bank

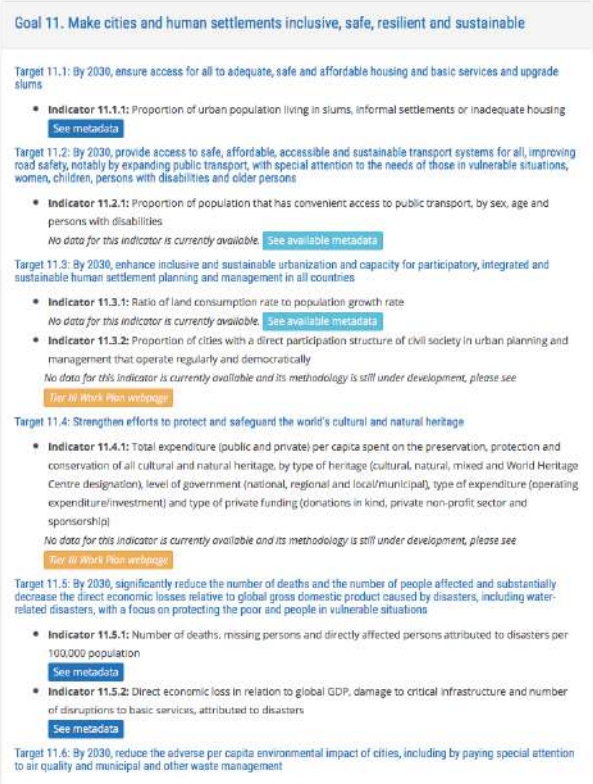
SDG Indicators Metadata repository

Tier 1: established methodology and data available

Tier 2: established methodology but data not regularly produced by countries

Tier 3: no established methodology and standards or being developed/tested.





Goal 11. Make cities and human settlements inclusive, safe, resilient and sustainable

Target 11.1: By 2030, ensure access for all to adequate, safe and affordable housing and basic services and upgrade slums

- **Indicator 11.1.1:** Proportion of urban population living in slums, informal settlements or inadequate housing
  See metadata

Target 11.2: By 2030, provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons

- **Indicator 11.2.1:** Proportion of population that has convenient access to public transport, by sex, age and persons with disabilities
  No data for this indicator is currently available. See available metadata

Target 11.3: By 2030, enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management in all countries

- **Indicator 11.3.1:** Ratio of land consumption rate to population growth rate
  No data for this indicator is currently available. See available metadata
- **Indicator 11.3.2:** Proportion of cities with a direct participation structure of civil society in urban planning and management that operate regularly and democratically
  No data for this indicator is currently available and its methodology is still under development, please see
  Tier III Work Plan webpage

Target 11.4: Strengthen efforts to protect and safeguard the world's cultural and natural heritage

- **Indicator 11.4.1:** Total expenditure (public and private) per capita spent on the preservation, protection and conservation of all cultural and natural heritage, by type of heritage (cultural, natural, mixed and World Heritage Centre designation), level of government (national, regional and local/municipal), type of expenditure (operating expenditure/investment) and type of private funding (donations in kind, private non-profit sector and sponsorship)
  No data for this indicator is currently available and its methodology is still under development, please see
  Tier III Work Plan webpage

Target 11.5: By 2030, significantly reduce the number of deaths and the number of people affected and substantially decrease the direct economic losses relative to global gross domestic product caused by disasters, including water-related disasters, with a focus on protecting the poor and people in vulnerable situations

- **Indicator 11.5.1:** Number of deaths, missing persons and directly affected persons attributed to disasters per 100,000 population
  See metadata
- **Indicator 11.5.2:** Direct economic loss in relation to global GDP, damage to critical infrastructure and number of disruptions to basic services, attributed to disasters
  See metadata

Target 11.6: By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management

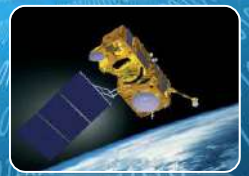
https://unstats.un.org/sdgs/metadata/

SDG #	Urban Indicators	Custodians	Tier
11.1.1	Slums and informal settlements	UN-Habitat	I
11.2.1	Access to public transport	UN-Habitat	II
11.3.1	Sustainable urbanisation	UN-Habitat	II
11.6.2	Urban air pollution	WHO	I
11.7.1	Urban (green) public areas	UN-Habitat	III

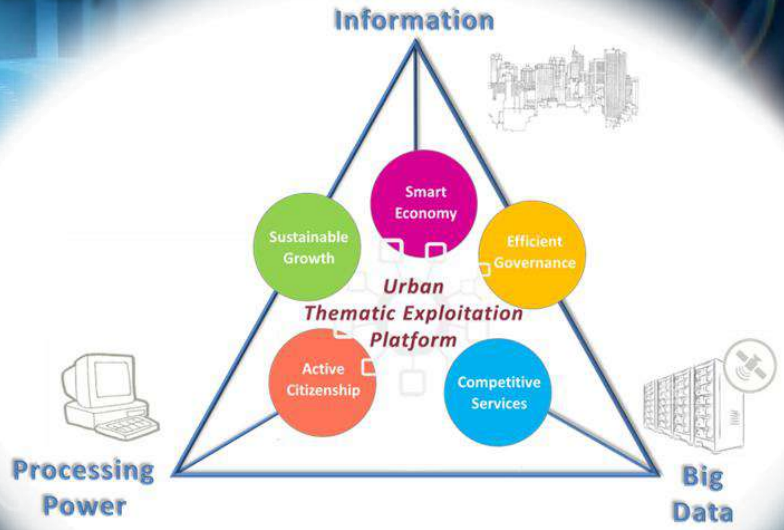
Big Data Era

Advent of steady satellite data streams

Sentinels Fleet



>15 TB per day



High Performance Computing Infrastructures

Building on ICT advances

TEPs, collaborative "big data" Thematic Exploitation Platforms

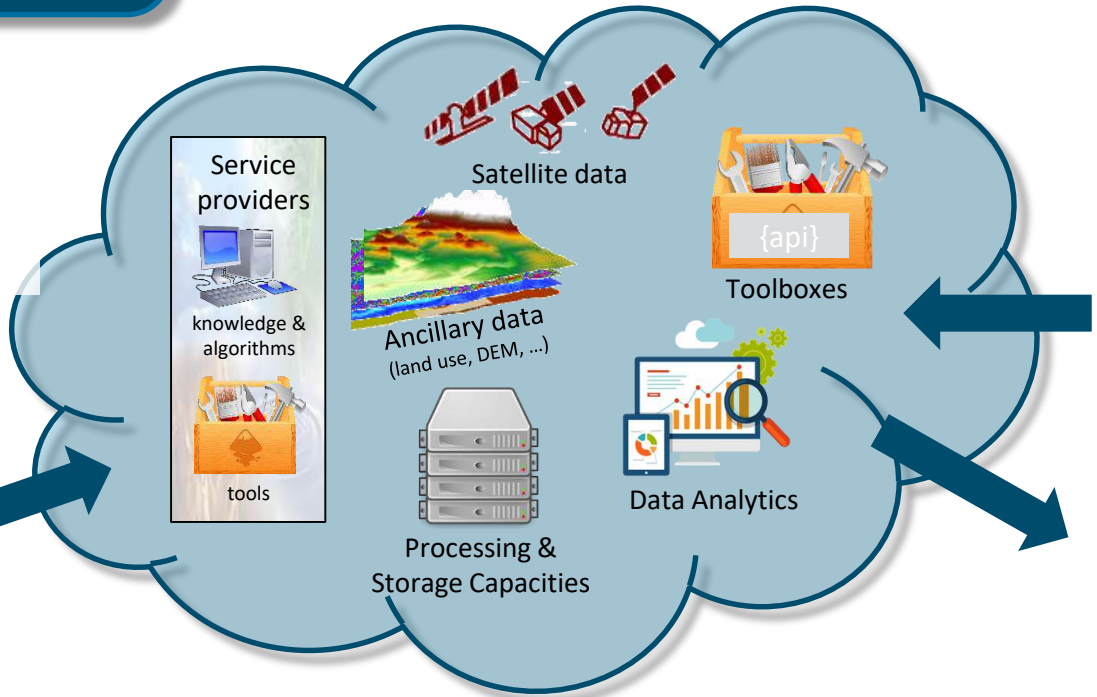
The power of the Cloud
The power of Partnerships

"Bringing the users to the data"

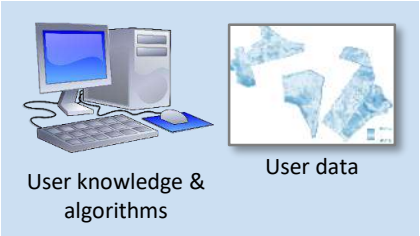
Simplify the extraction of information from EO data
Enable large scale exploitation of EO data
Stimulate innovation with EO data

Platforms as enabling technology

Mobile data
Crowdsourcing
citizen science



Remote access for users



User generated results

Urban TEP (U-TEP)

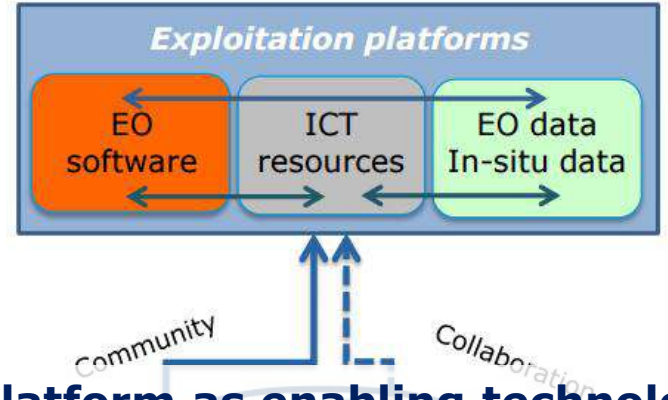
a collaborative on-line infrastructure for multi-source data processing and analytics in urban applications

… all **data** and **tools** needed to

… to access or generate **actionable information**

… in support of **sustainable** and **livable cities**…

… available at **one place**



Platform as enabling technology

Explore thematic data | Task on-demand analyses | Develop and offer content | Learn more about users and applications

urban tep

Innovative All-in-One and End-To-End Solutions.

- All data, tools and ICT resources available in one platform (*convenience*).
- Provision of solutions to transform raw data into ready-to-use information (*applicability*).
- Data, results and technology sharing (*societal benefit*).

Matchlessness Product and Service Portfolio

- Unprecedented thematic scope and spatial detail (*uniqueness*).
- Global coverages and long-term monitoring capability (*completeness*).
- On-demand capability (*timeliness*).
- Multi-source data (*interdisciplinary*).

Effective Enabling Technologies.

- high-performance processing (*efficiency*).
- Data visualization and analytics toolbox (*value-adding*).

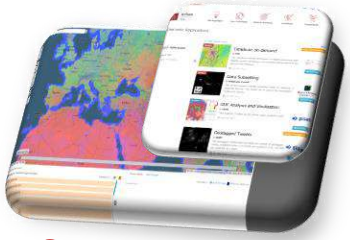
Open and Participatory Platforms based on modern ICT technologies that enables to easily exploit and generate thematic information on the status and development of urban environment

https://urban-tep.eo.esa.int

urban tep

Background | Use Scenarios | Data & Services | Quick Start | Activities | Partners

Migration to DIAS under study



Geobrowser & Catalogue

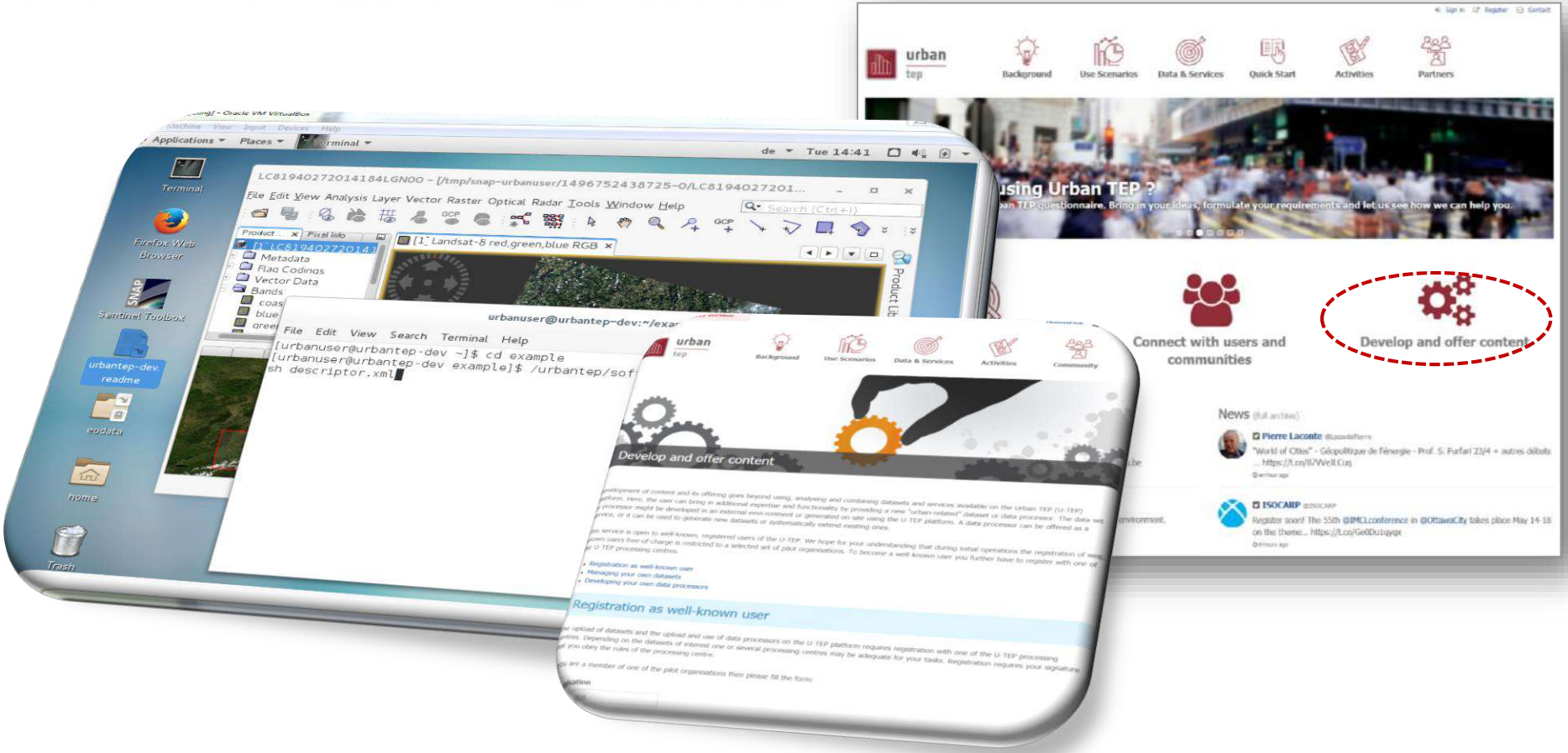
Visualization and Analytics

Developer Environment

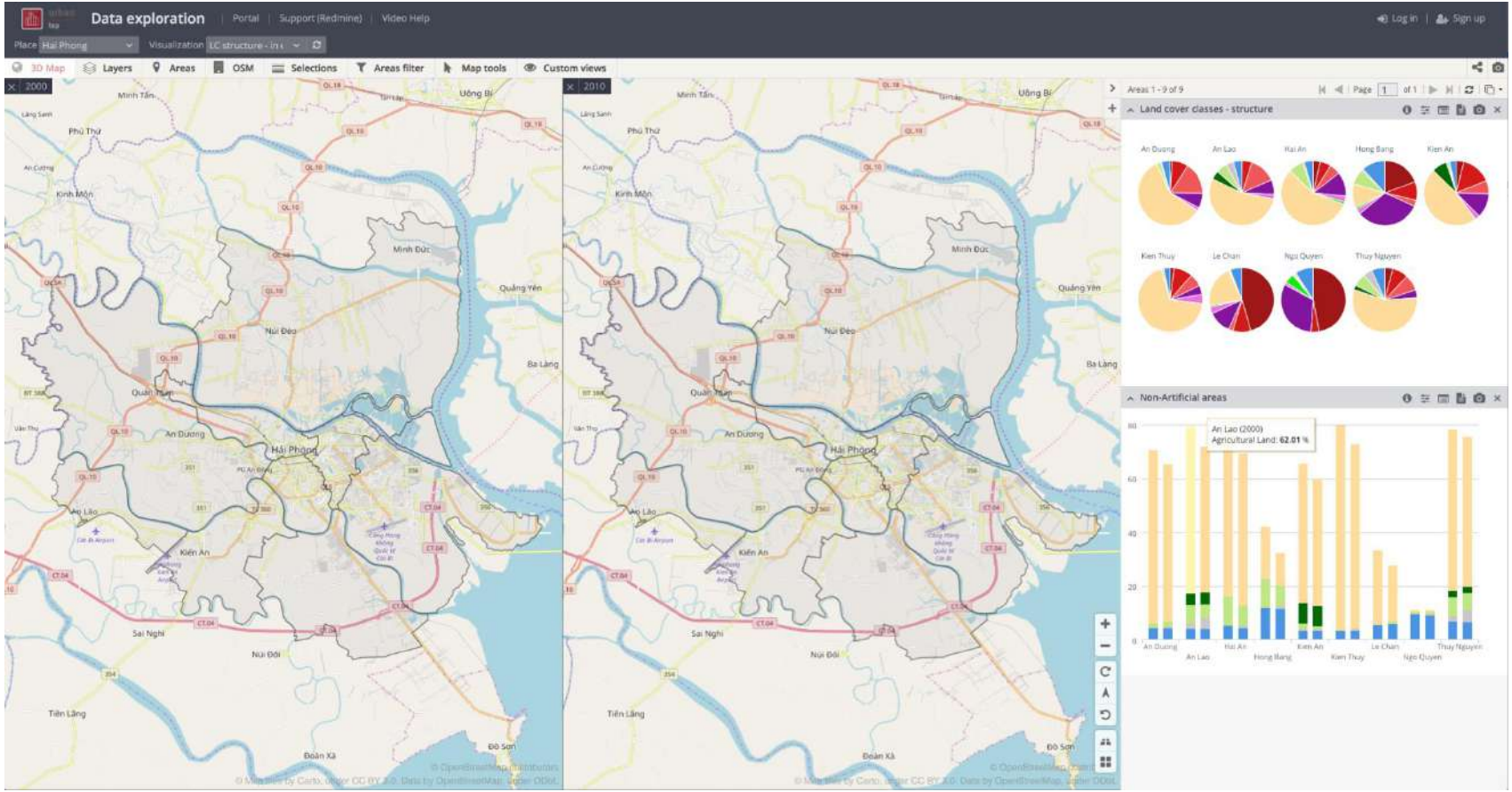
User Forum

Three **processing clusters** with standardised interfaces (OGC, WPS, WMS)

Processor Development Environment



Visualization and Analytics Toolbox (VISAT)



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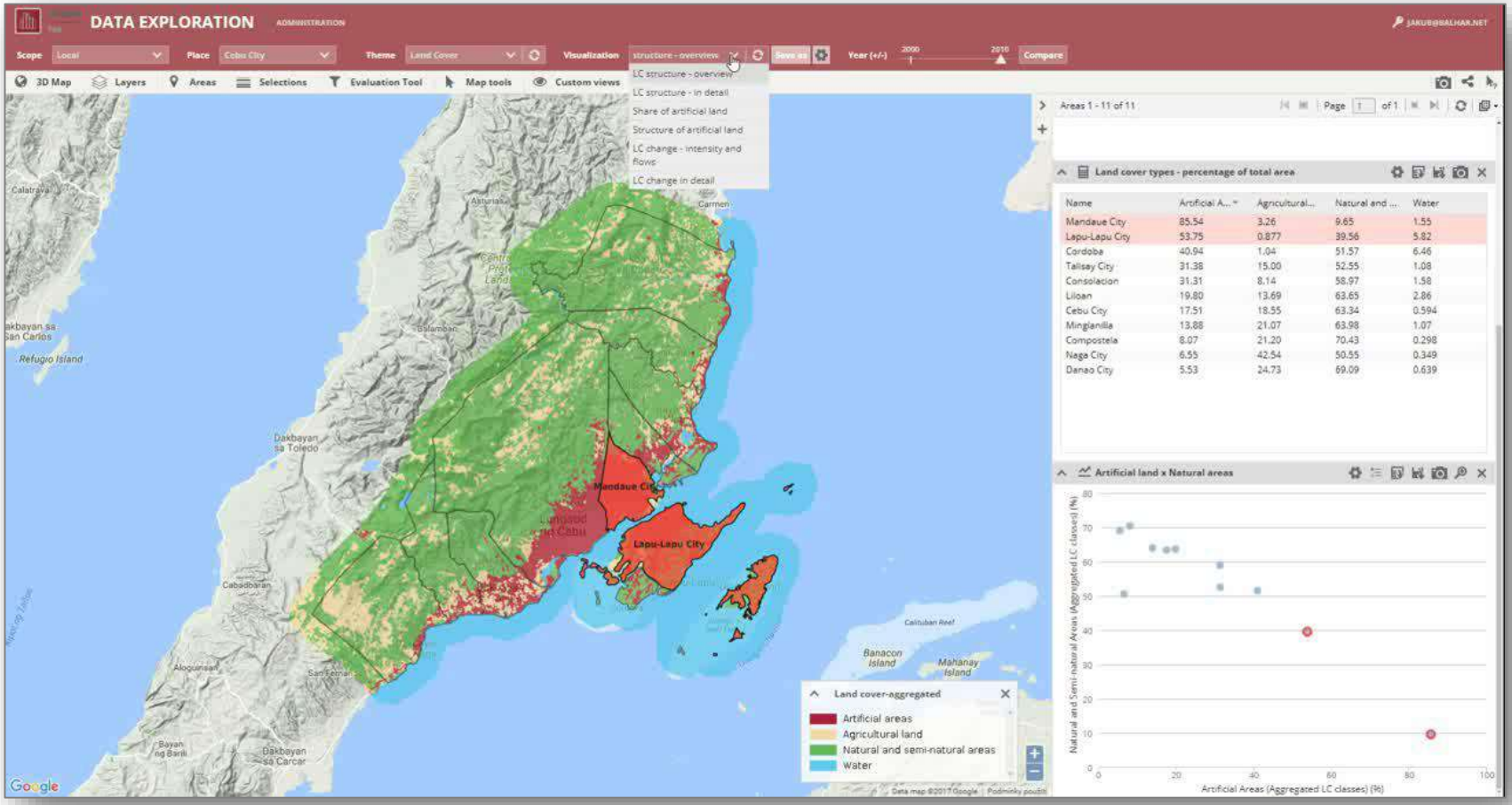
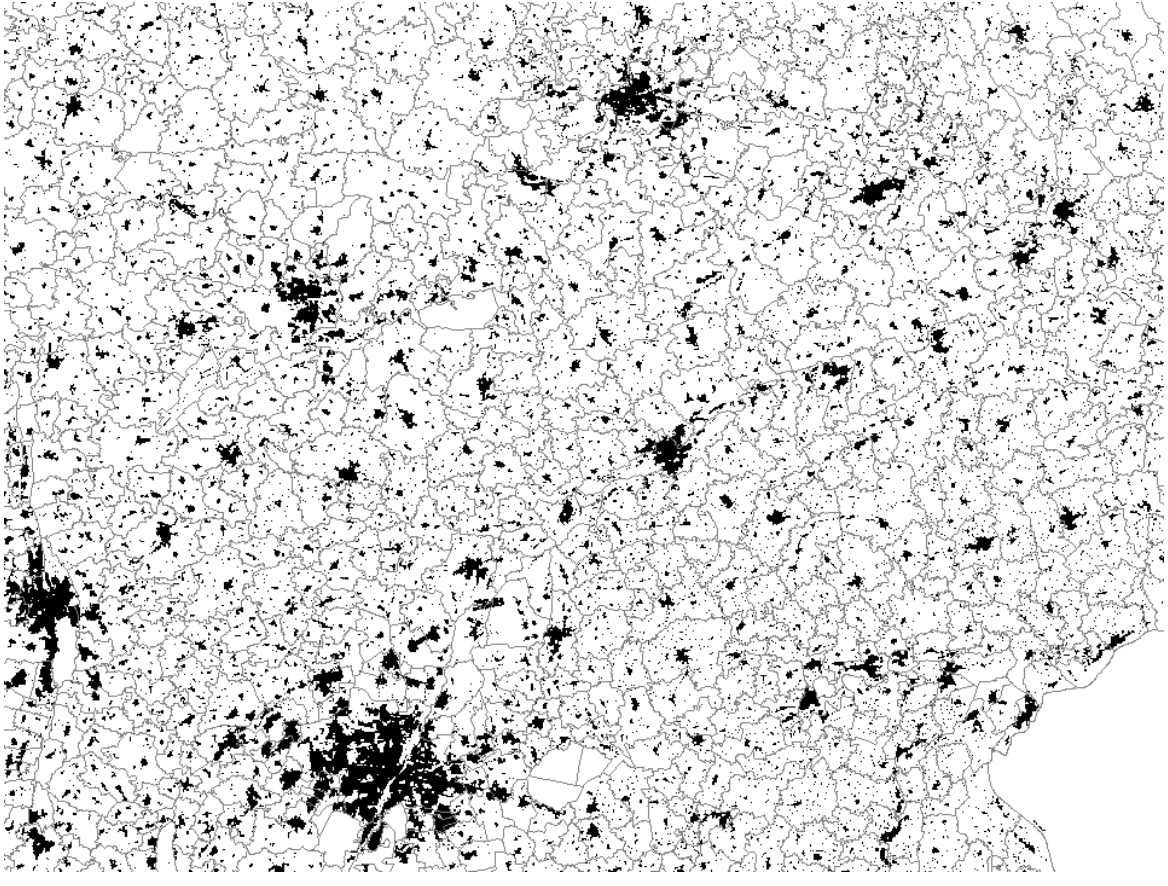


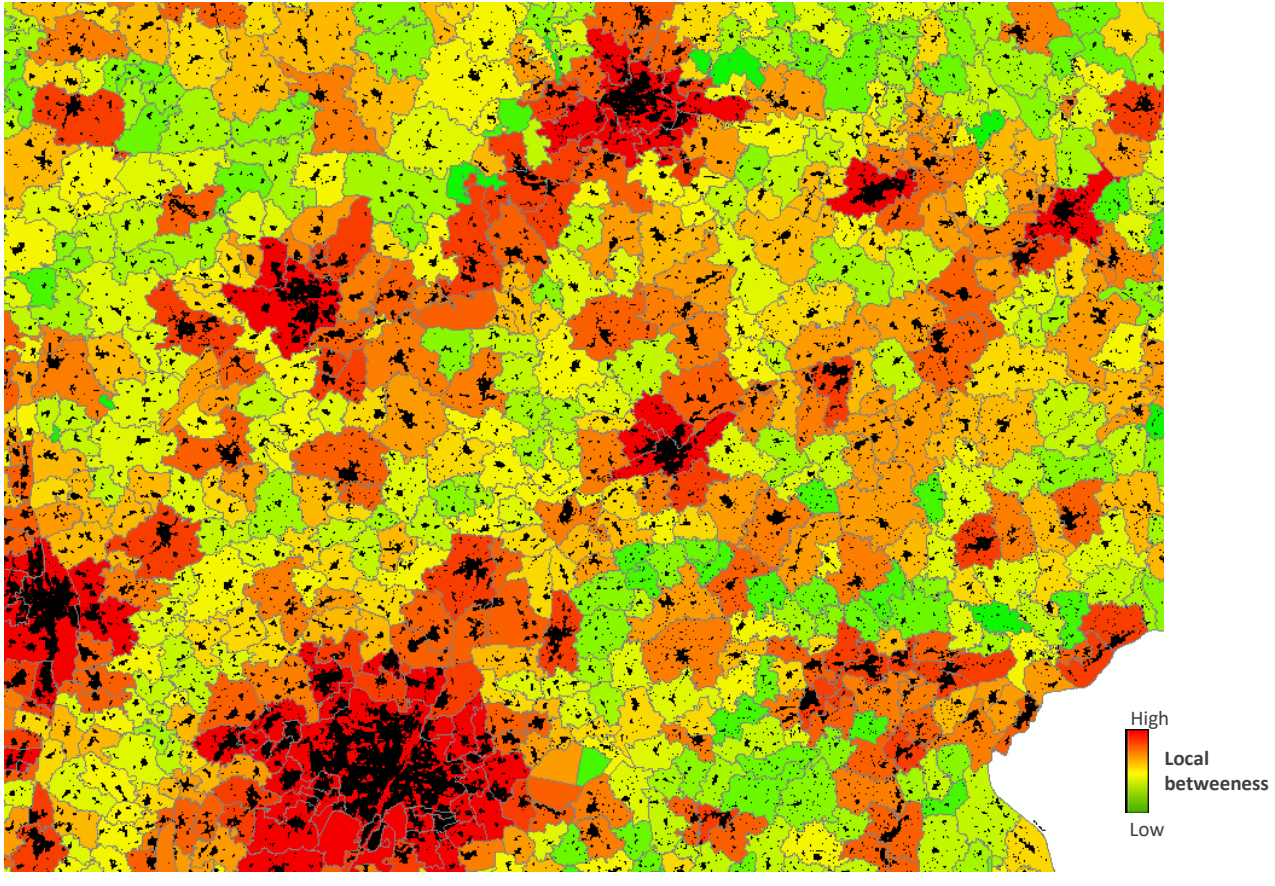
Spatial Analysis: settlement properties & pattern



GUF-NetS

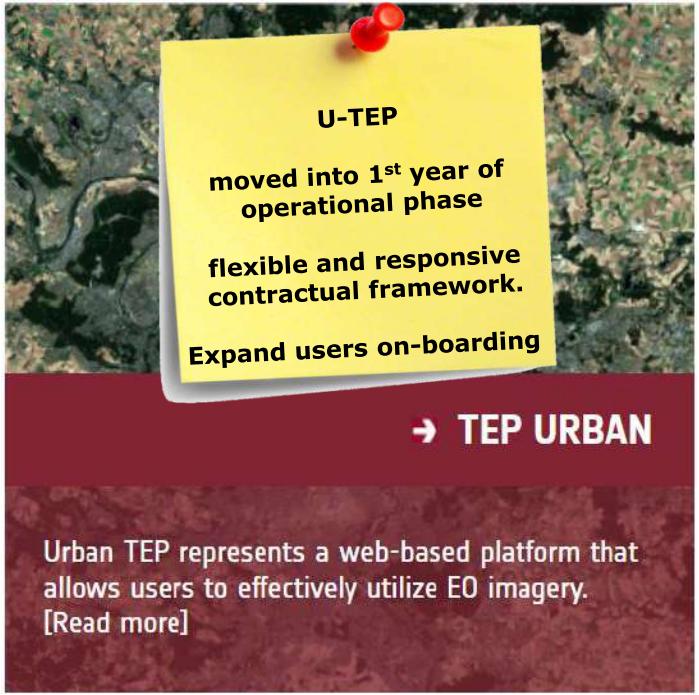
Global Urban Footprint

Spatial Analysis: settlement properties & pattern



GUF-NetS

Towards an urban community driven platform



Early Adopters

WORLD BANK GROUP

OECD

WFP

GEO

Global Platform for Sustainable Cities

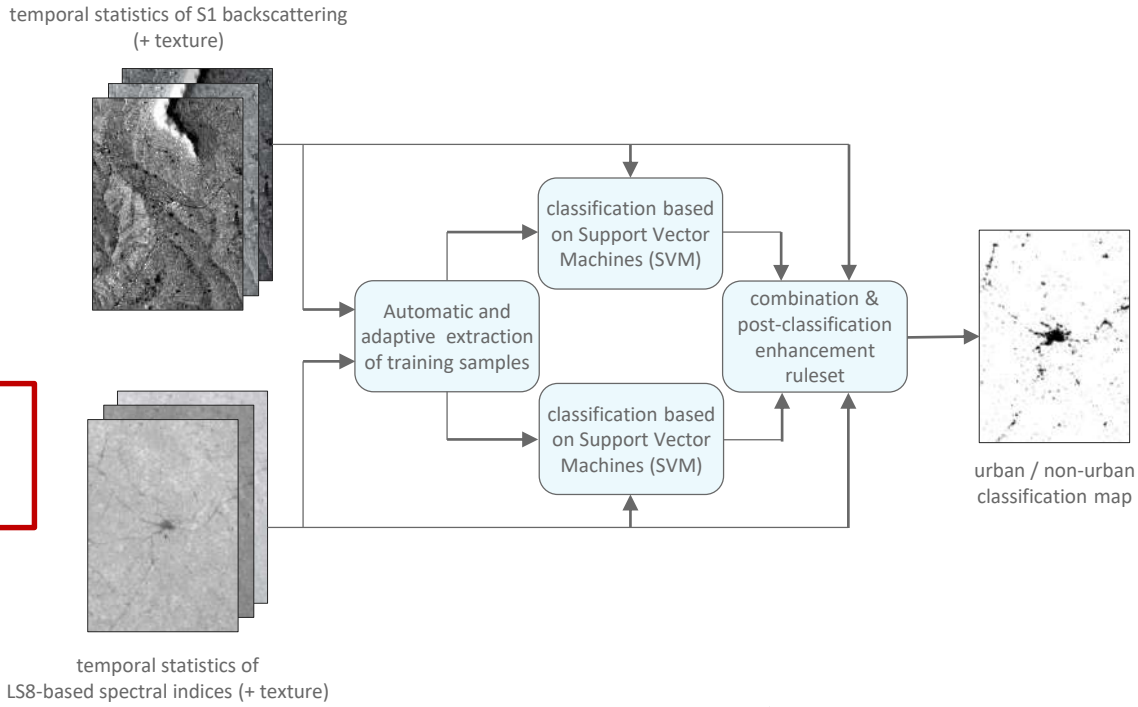
BILL & MELINDA GATES foundation

world pop

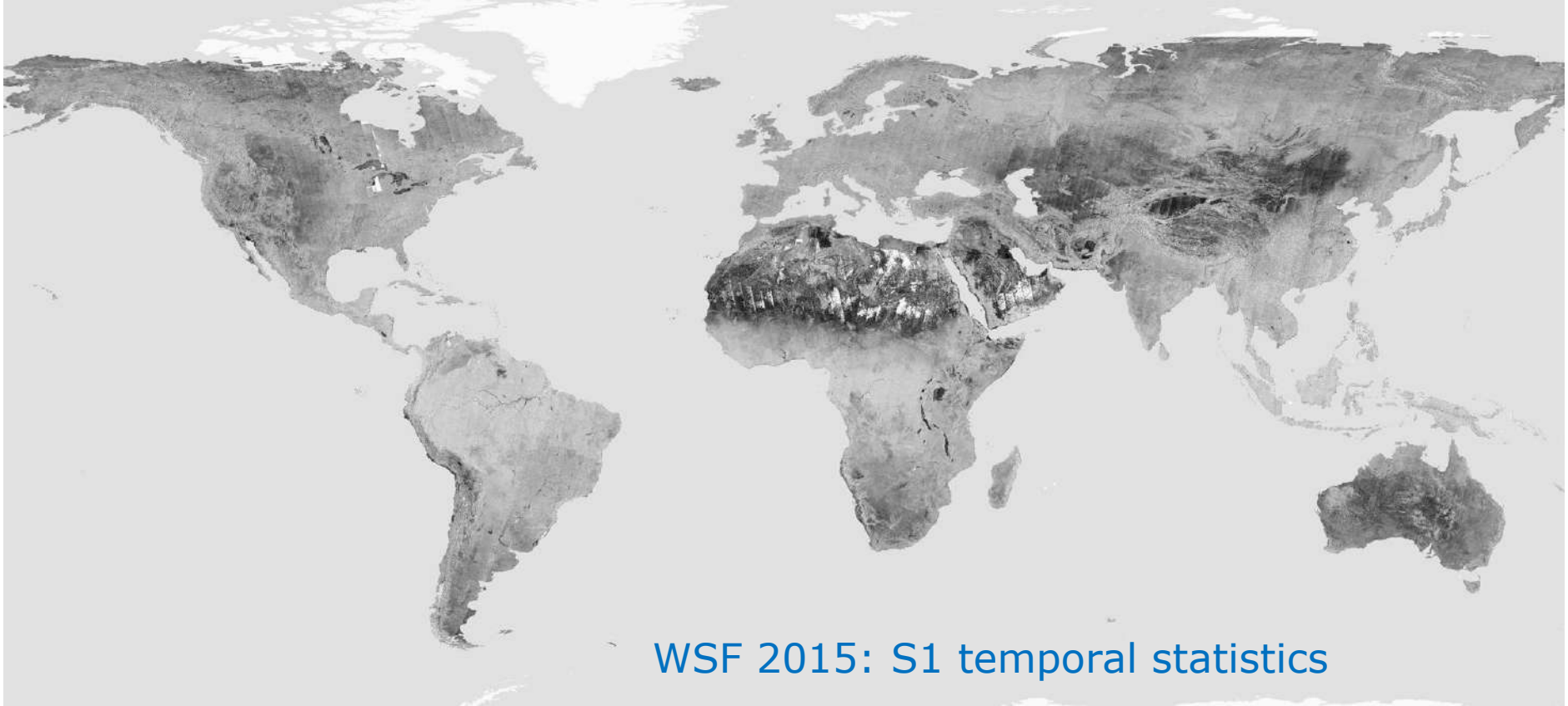
unicef

World Settlement Footprint (WSF) 2015

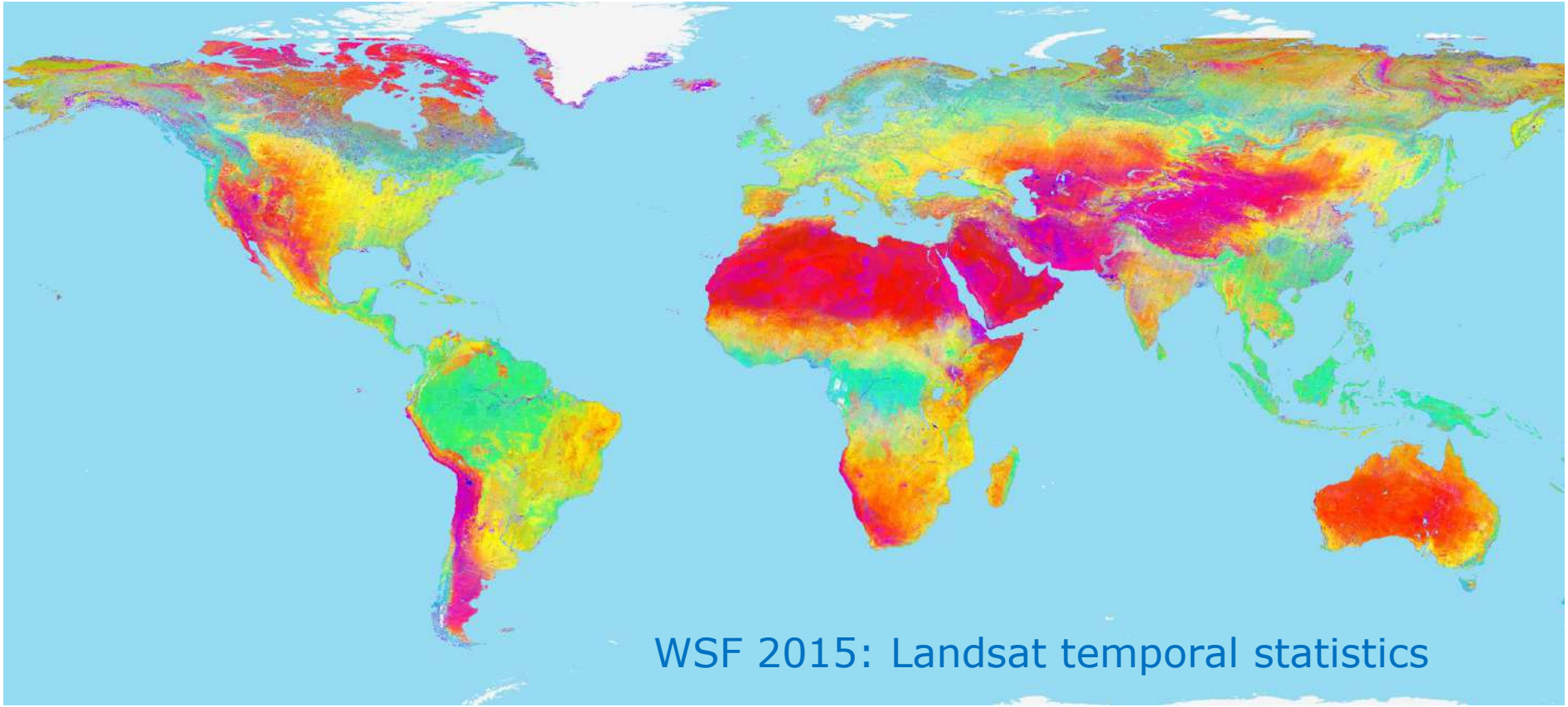
- Global map of human settlements derived by jointly exploiting multi-temporal optical and SAR imagery.
- Open and free dataset based on freely accessible imagery.
- Response to global data needs on settlement for informed policies on urban development
- Urban, rural and peri-urban areas
- **Innovative solution: Temporal dynamics of urban settlements are different than those of all other non-urban classes.**
- Perspectives for future WSF updates (WSF 2018 based on S1/S2, in preparation)



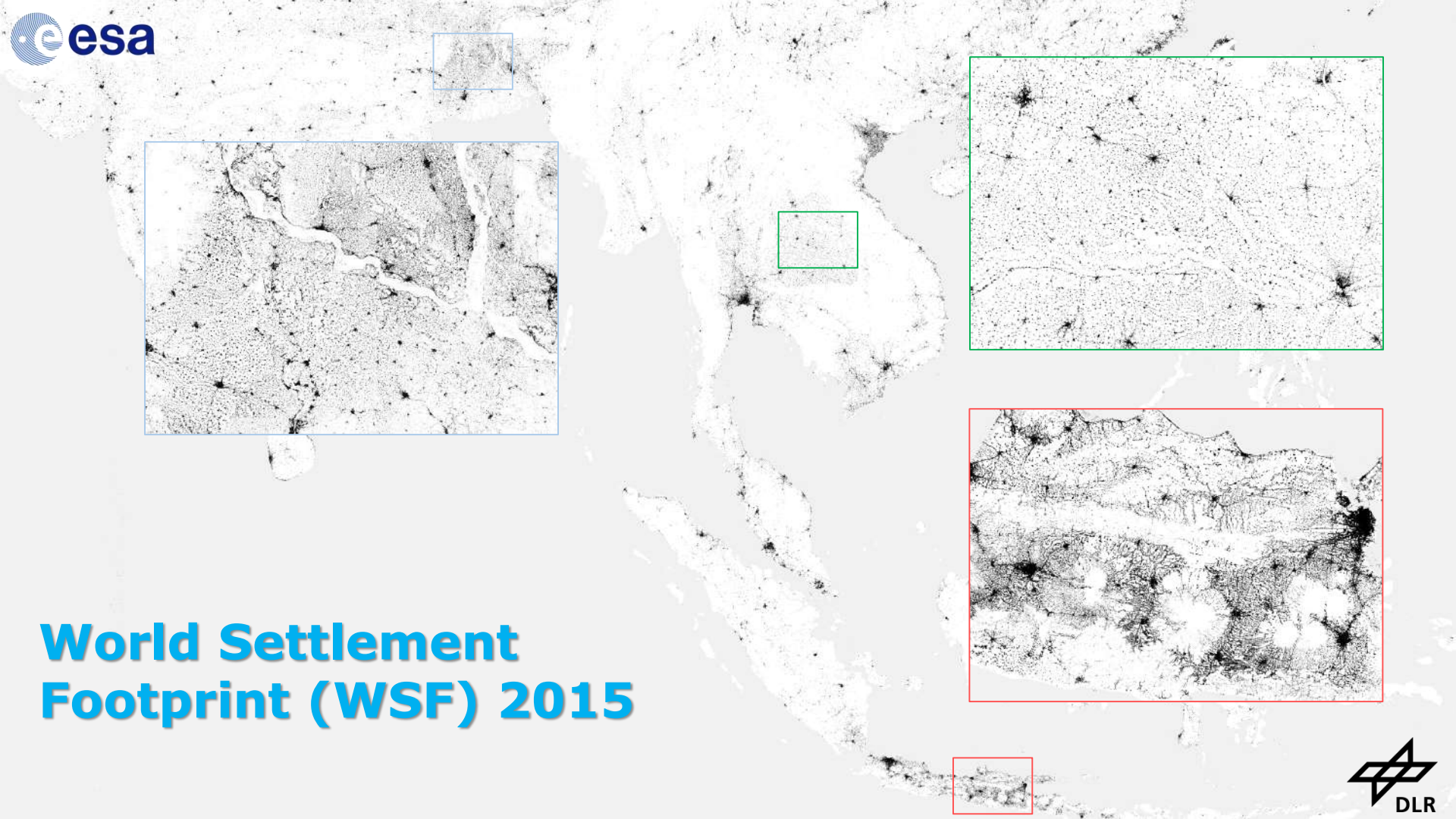
Engineered in SAR4Urban, powered by U-TEP



~250.000 Sentinel-1 scenes **2014-2015**	**2** Polarisations **5** temporal statistics	**10m** spatial resolution	**processed by Google Earth Engine**



~460.000 Landsat-8 scenes **2014-2015**	**6** spectral indices **5** temporal statistics	**30m** spatial resolution	**processed by U-TEP**

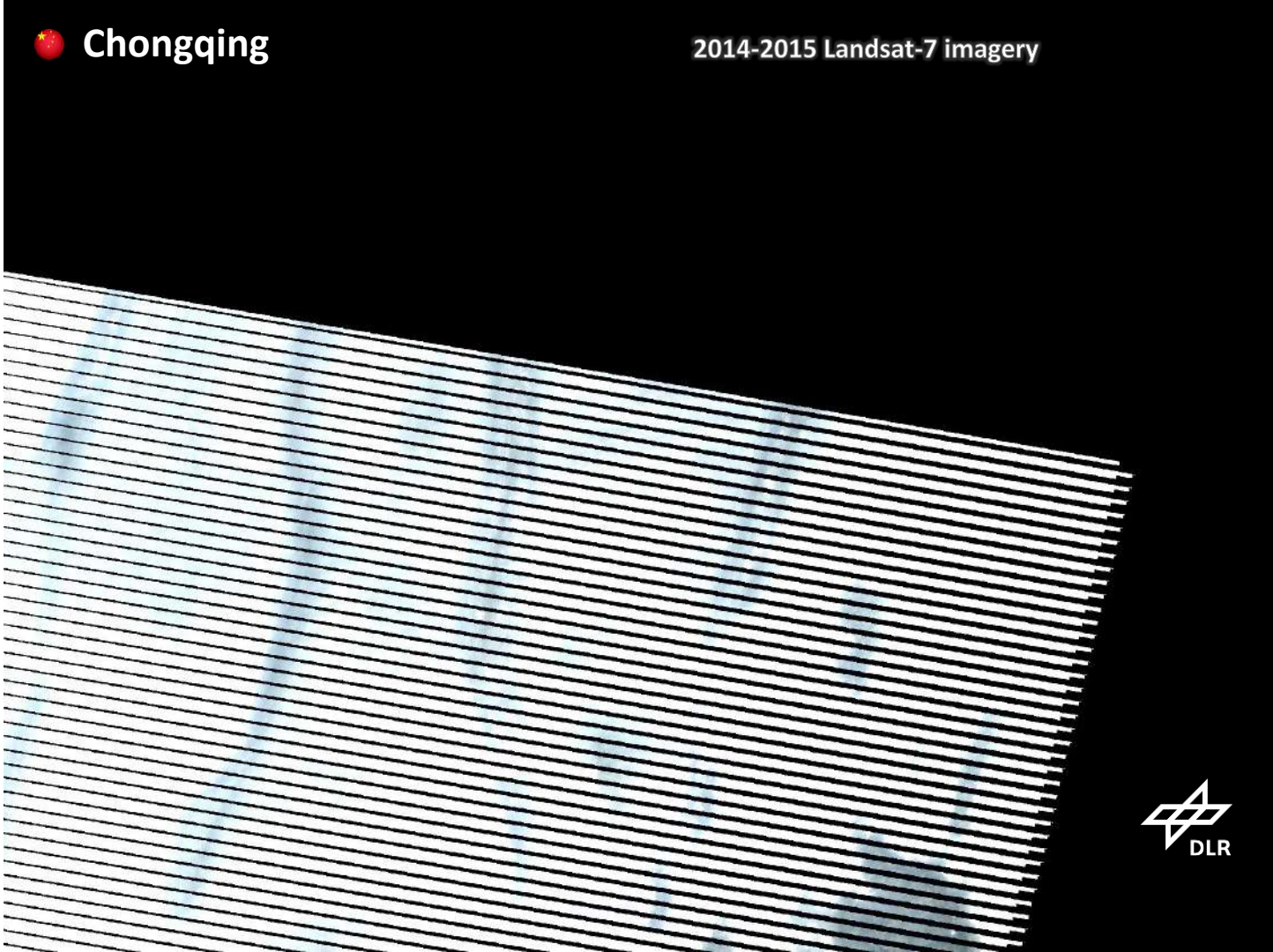


World Settlement Footprint (WSF) 2015

urban
tep
Marc.Paganini
WSF
GUF
GUF+
TimeScan
HAPS
Regional LU - LC
Geotagged Tweets
Ground Surface Movement
External Data
EO Free Text Search
Srinagarin Dam Reservoir
S1-L8 based
WSF 2015
finalised and validated
Released on U-TEP
at MUAS 2018
(October 2018)
S1-S2 based
WSF 2018
under development
To be released
in 2019 Q3
on U-TEP
2010-12-31
2010-12-31
20 km
Terradue
Current search result
Query results for series wsf2015
Total results 1
World Settlement Footprint (WSF) 2015 - SE Asia

WSF Evolution

- Adapt methodology for outlining past urban extent.
- based solely on multi-temporal Landsat-5/7.
- globally at high temporal frequency (at least 5y)
- specific ruleset for excluding temporal inconsistencies
- In collaboration with GEE
- Open and free release 2nd half 2019



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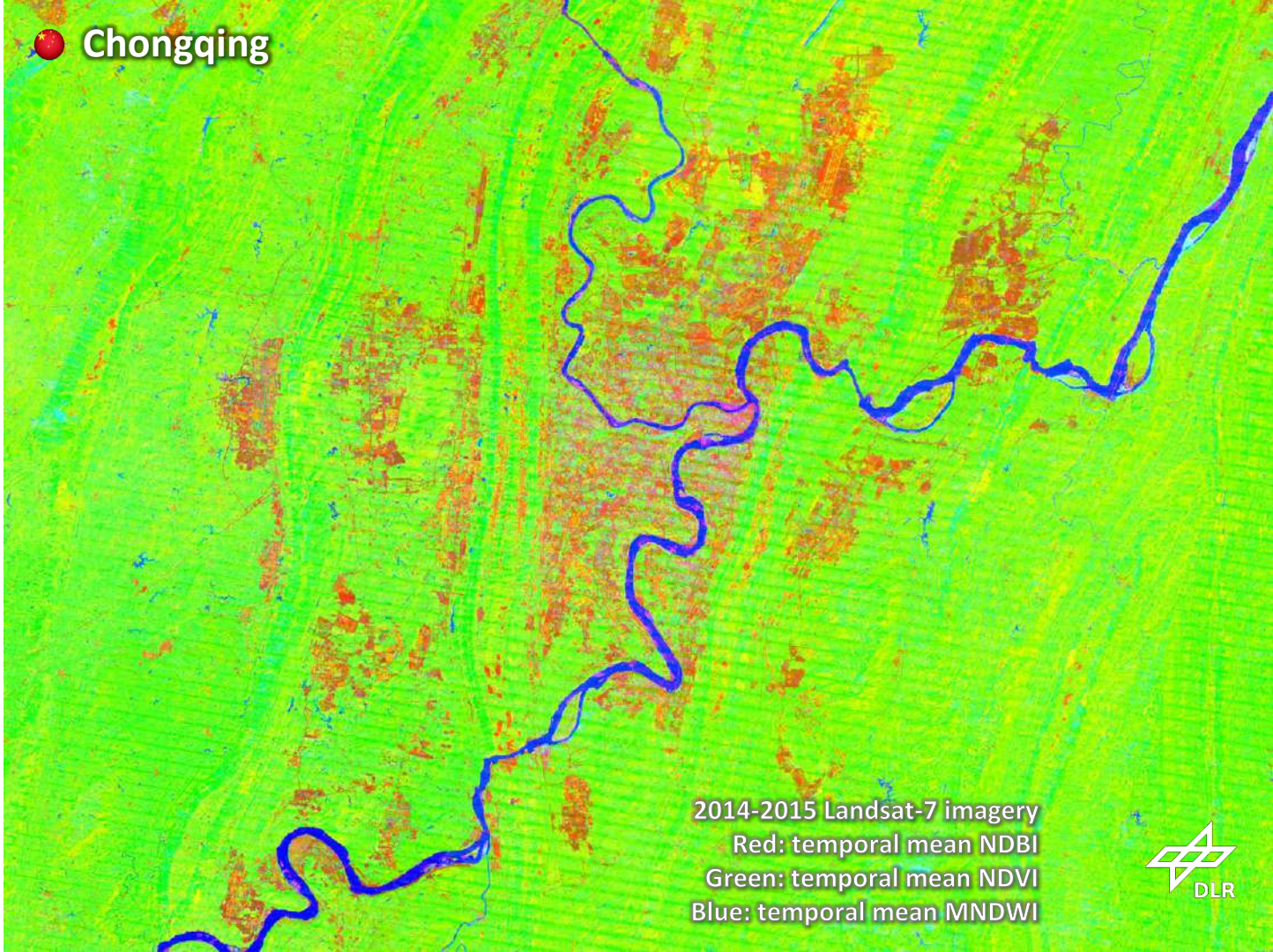


Monitoring urban development

Shanghai
1985-2015

urban tep

Monitoring urban development

Shanghai
1985

urban tep

Monitoring urban development

Shanghai
1990

Monitoring urban development

Shanghai
1995

urban tep

Monitoring urban development

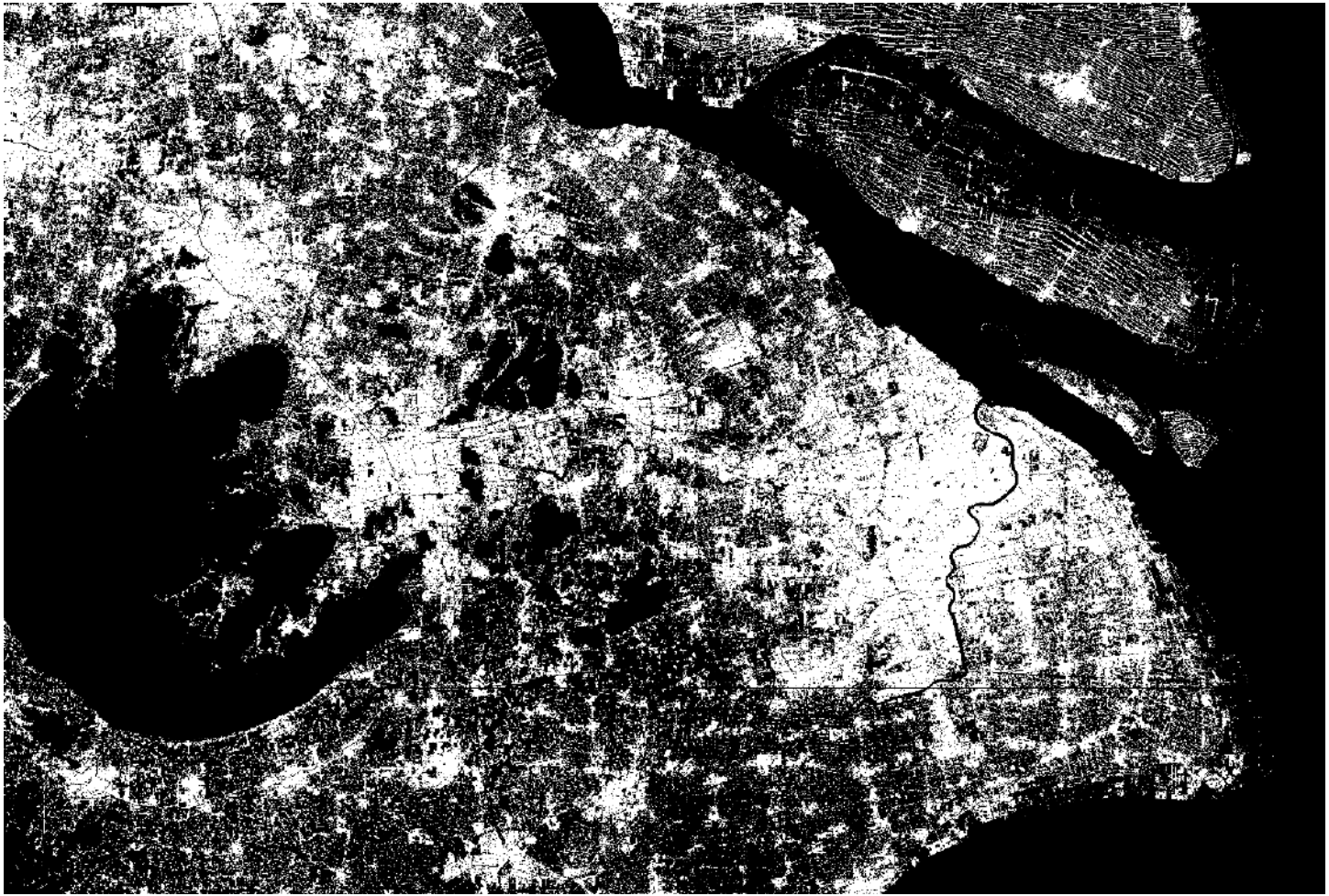
Shanghai
2000

urban tep

Monitoring urban development

Shanghai
2005

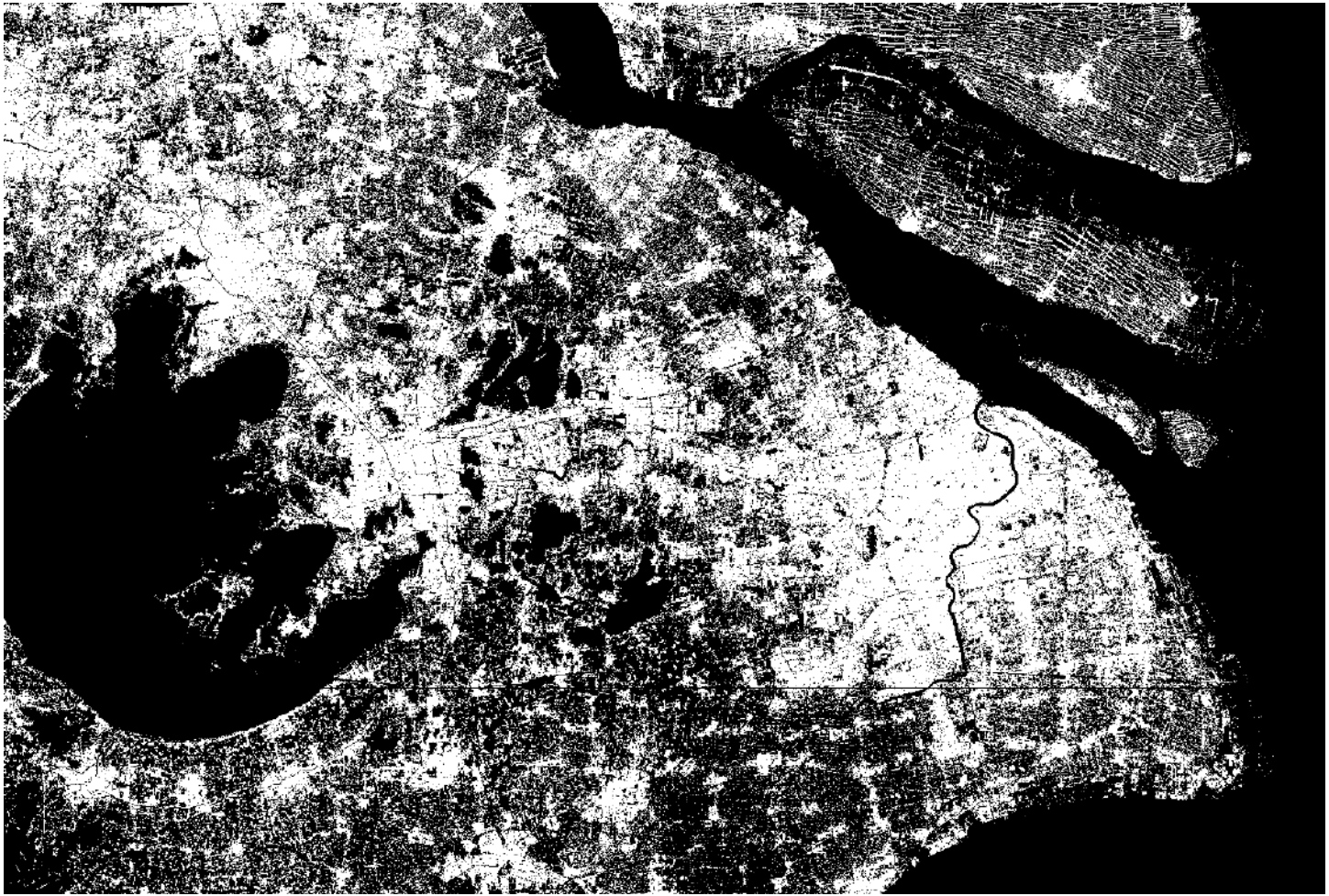
urban tep



Monitoring urban development

Shanghai
2010

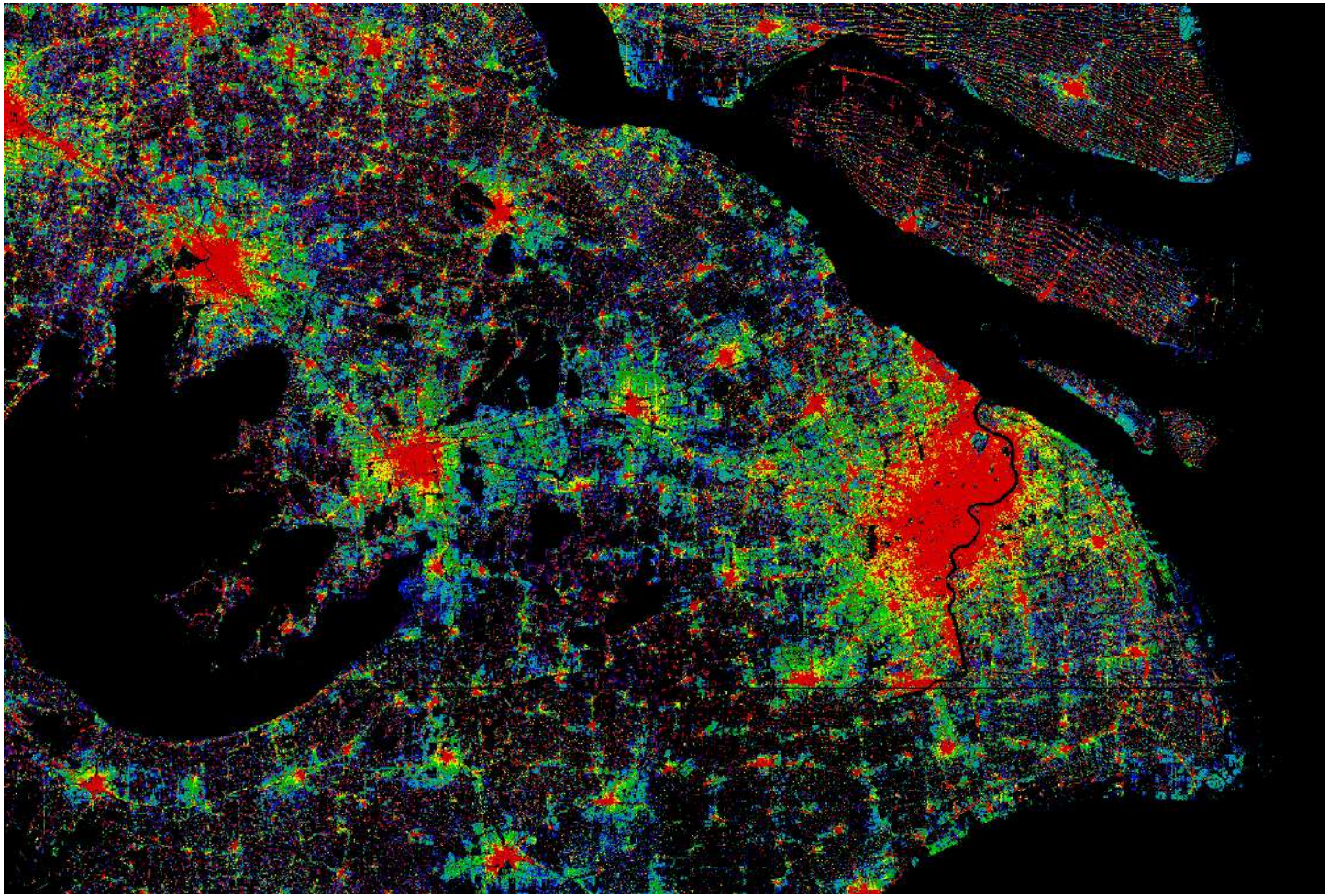
urban tep



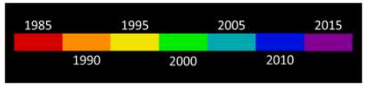
Monitoring urban development

Shanghai
2015

urban tep

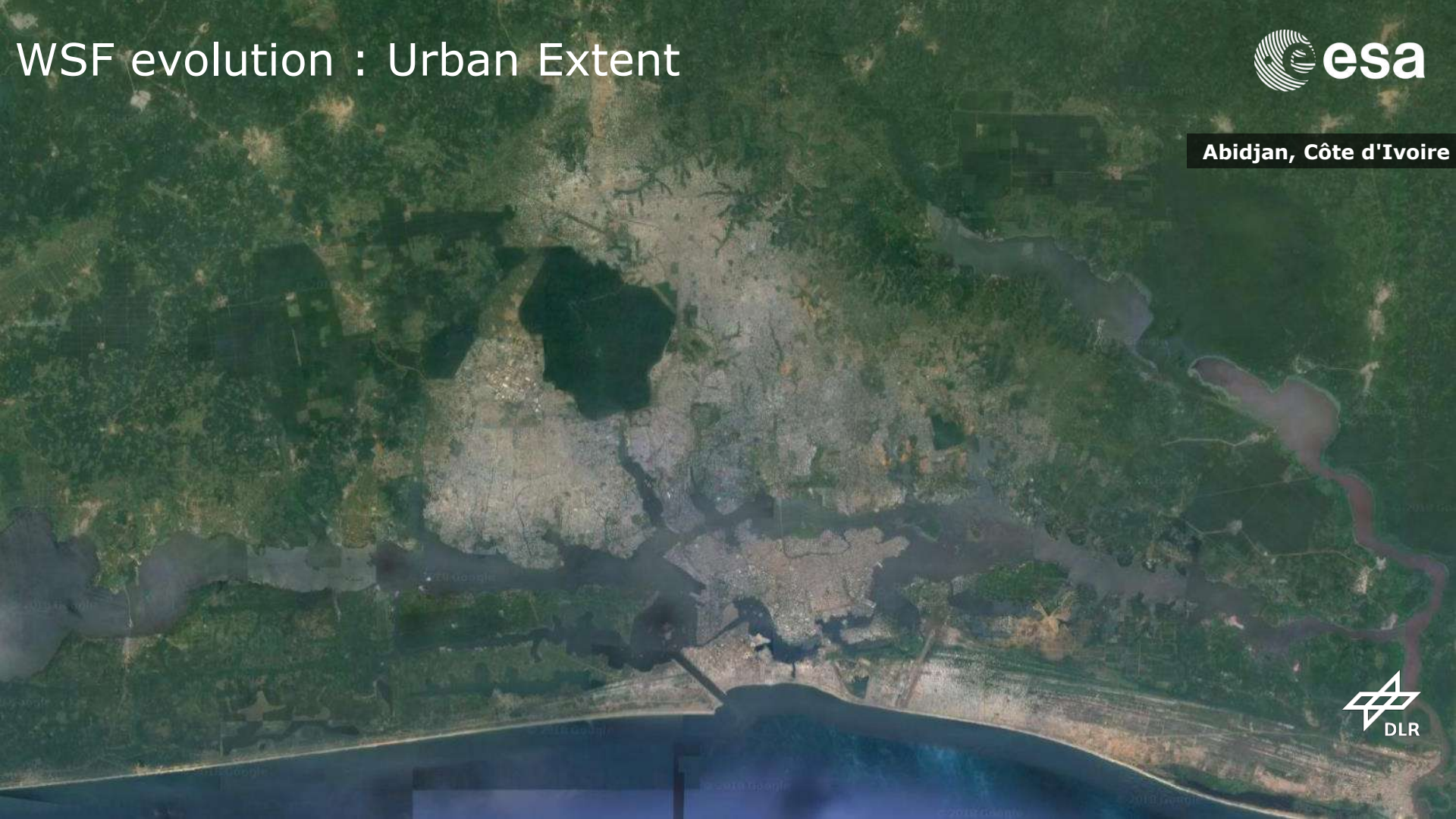


Monitoring urban development



urban tep

WSF evolution : Urban Extent



WSF evolution: Urban Extent

WSF evolution : Urban Extent

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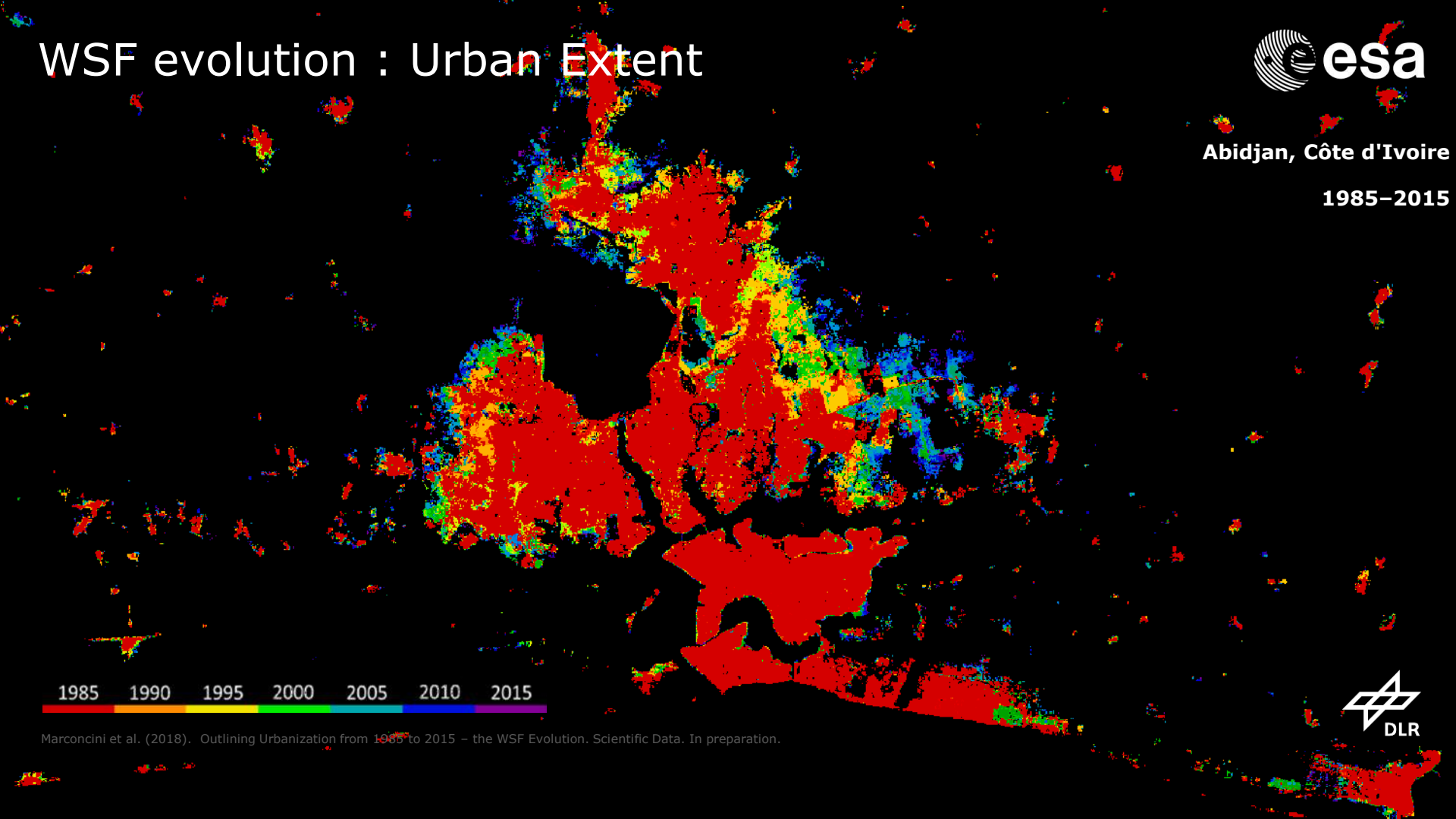
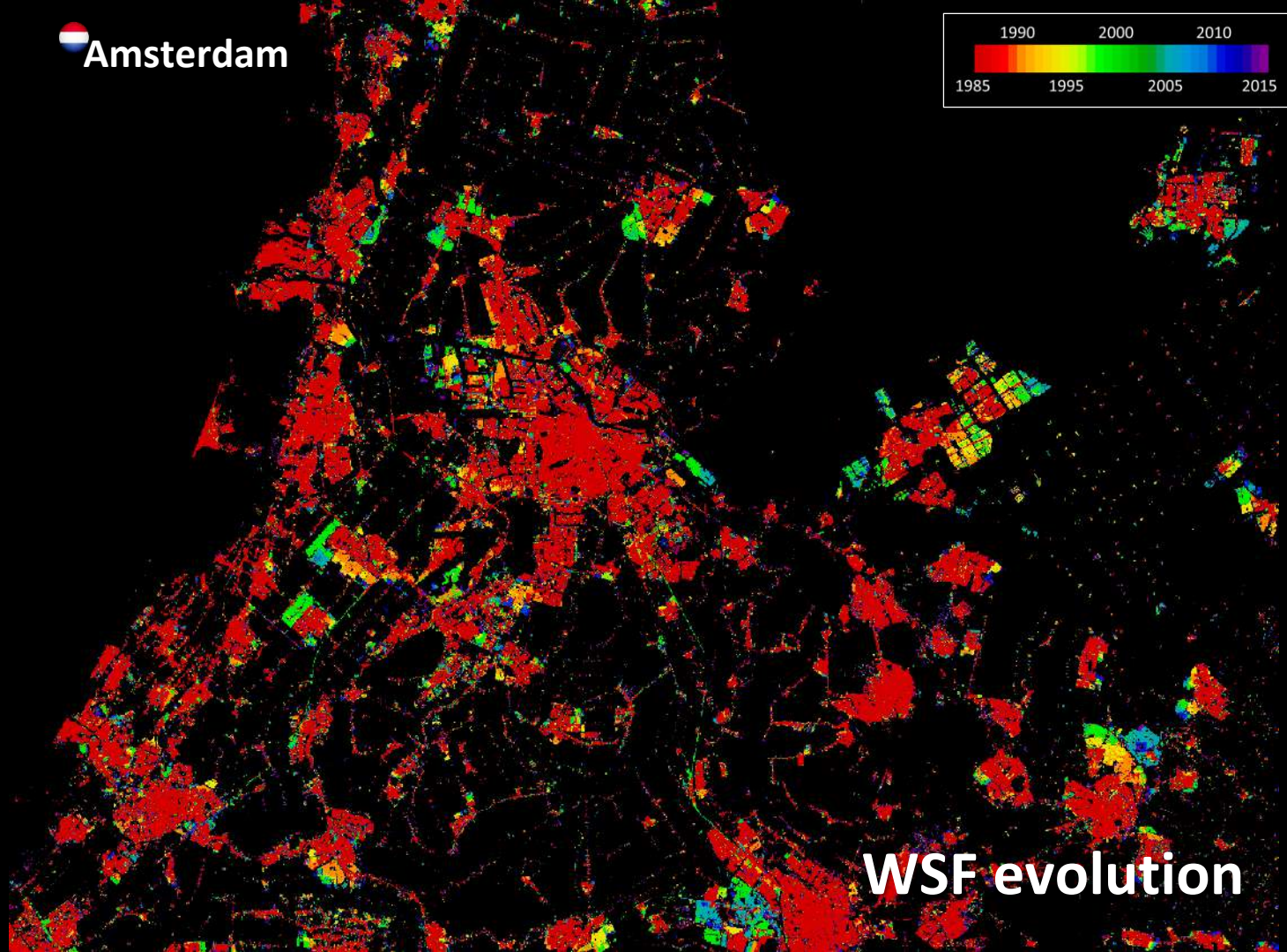
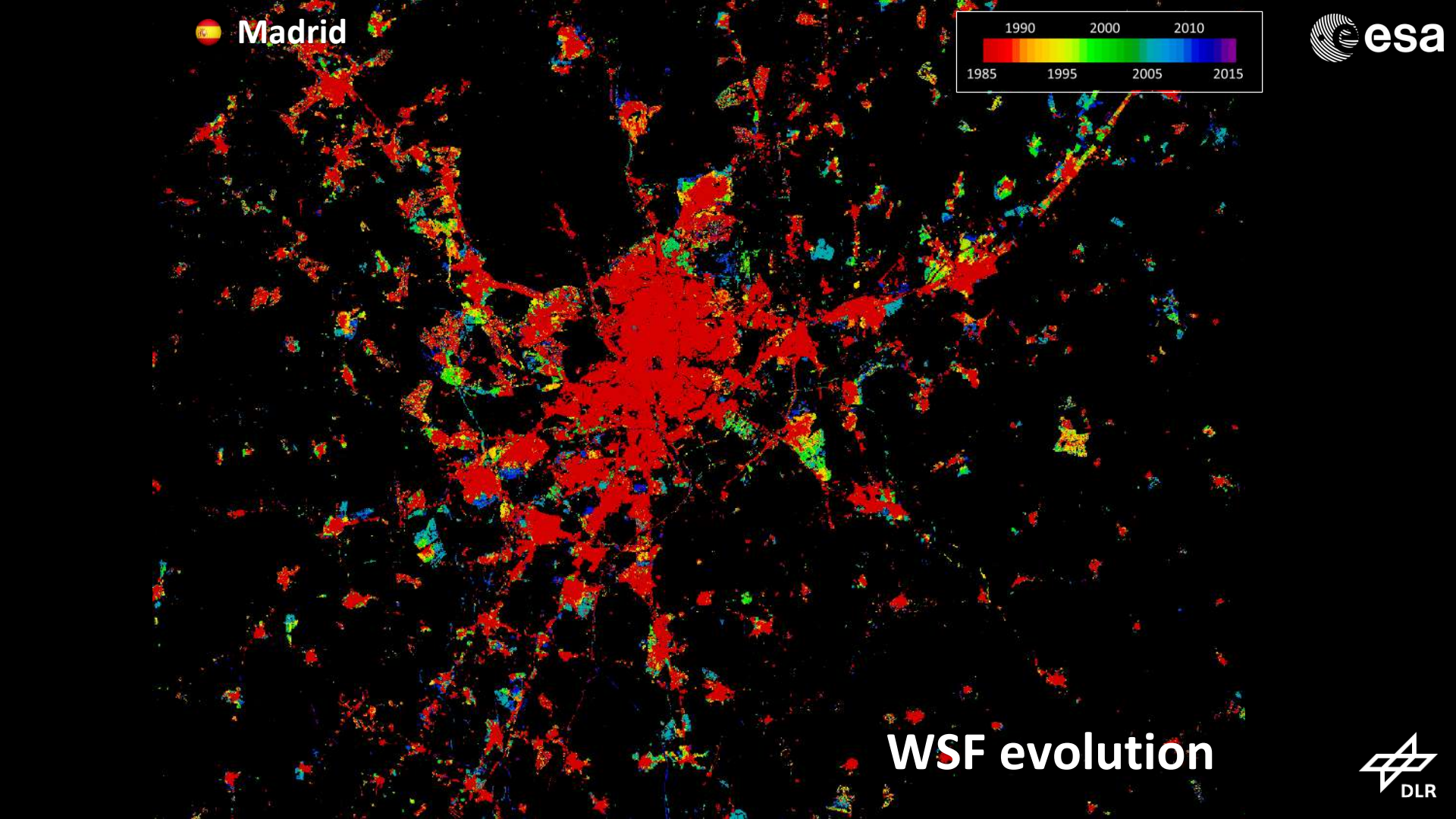
WSF evolution : Urban Extent



Marconcini et al. (2018). Outlining Urbanization from 1985 to 2015 – the WSF Evolution. Scientific Data. In preparation.


Amsterdam
1990
2000
2010
1985
1995
2005
2015
WSF evolution


Madrid
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1995
2005
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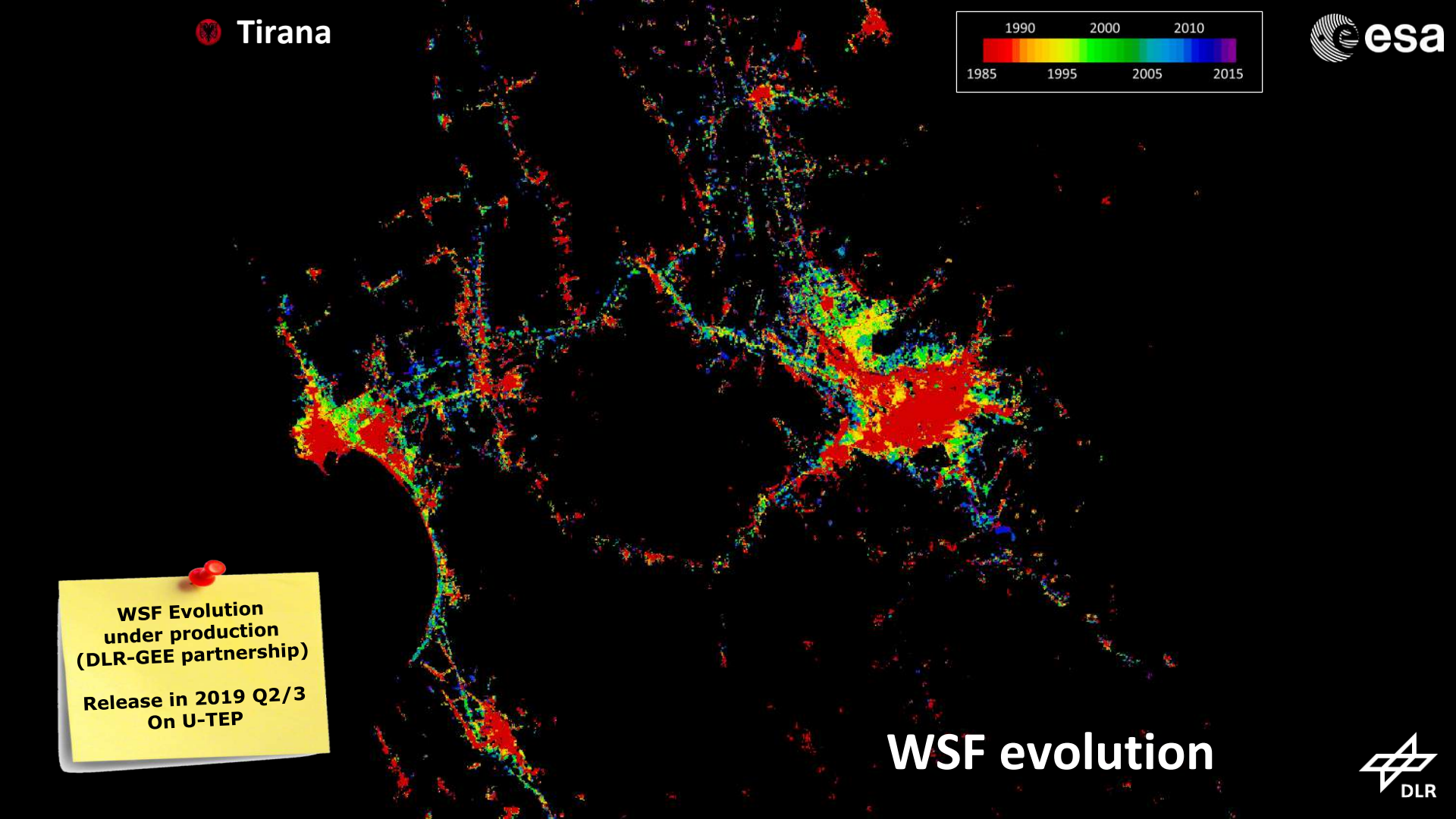
esa
WSF evolution
DLR


Tirana
1990
2000
2010
1985
1995
2005
2015
esa
WSF Evolution
under production
(DLR-GEE partnership)
Release in 2019 Q2/3
On U-TEP
WSF evolution
DLR

Mainstreaming Earth Observations in local communities systems and processes

EO for Sustainable Development-Urban" (EO4SD-Urban)

- Funded under the ESA EO4SD programmatic framework
- initiated in May 2016, lead by GAF AG.

Main objectives:

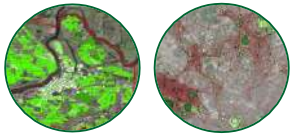
- Improve understanding of potential of EO applications for urban development, in partnership with International Finance Institutes (IFIs), Multi-Lateral Development Banks (MDBs) and developing countries.
- Mainstream EO applications in operational city development programmes.
- Export the EO offering of the European Value-added industry

EO Products for Urban Development

EO4SD Urban products, services and data analytics

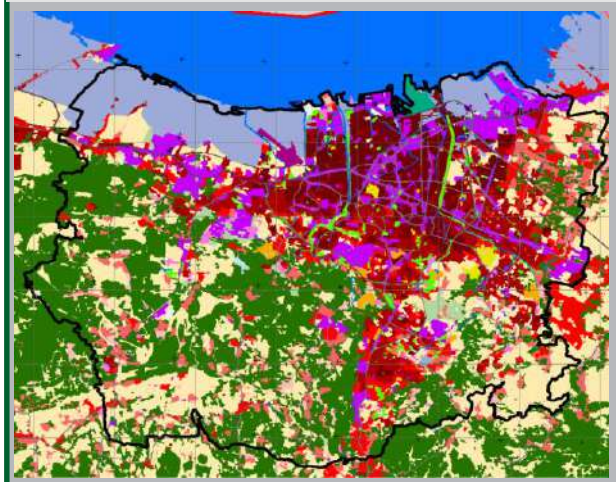
To be integrated on U-TEP in 2019

Green Areas/Networks



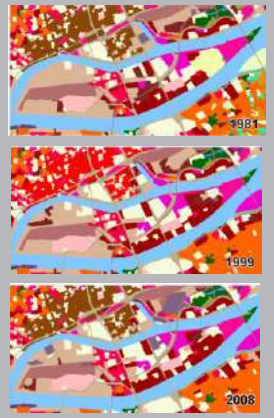
Urban Extent and Change

Baseline Urban Products
Urban and Peri-Urban LU /LC



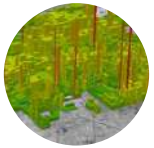
Detailed

Change



Building Footprint

Population Density



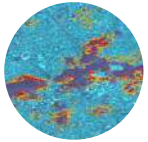
Waste Sites

Transport Infrastructure

Informal Settlements

Flood Risk

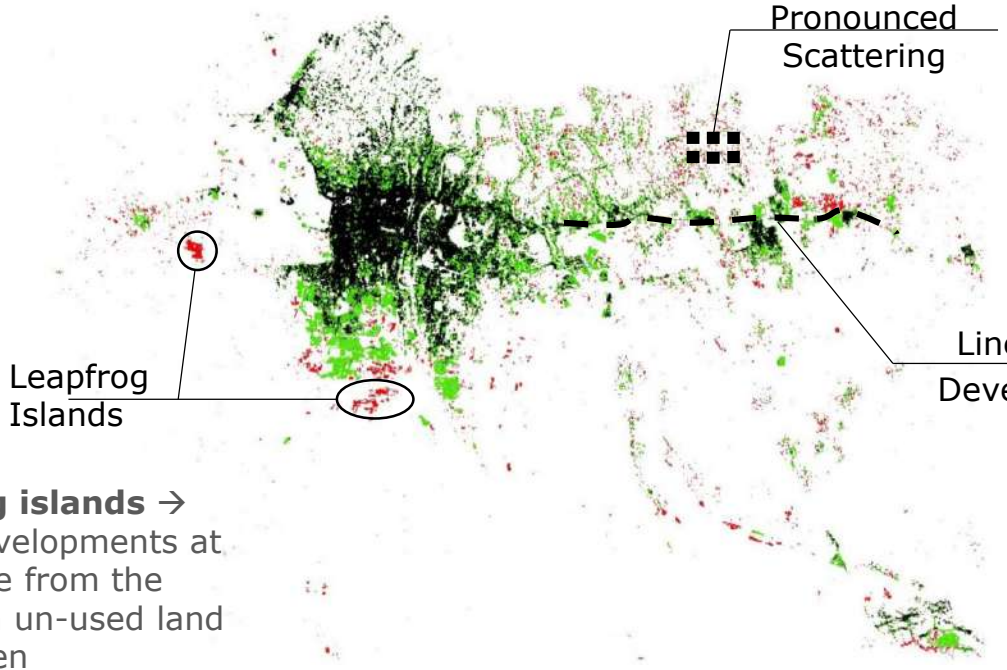
Landslide Risk



Terrain Motion

Understanding Urban Growth Patterns

Arusha City, Tanzania (2000 – 2015)



pronounced scattered development patterns in the north-east

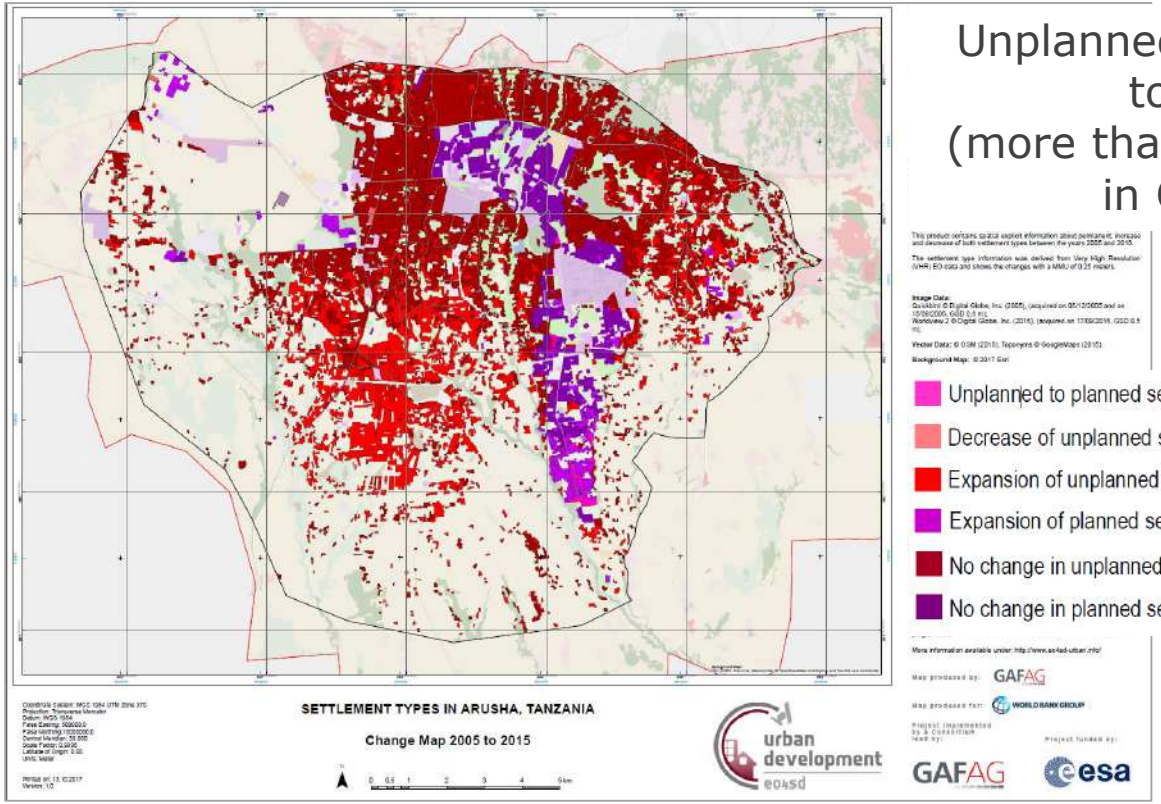
Alongside major roads (the Arusha-Himo Road).

Leapfrog islands → urban developments at a distance from the Core with un-used land in-between

Leapfrog Growth
Edge and Infill Growth

Unplanned vs planned Settlements

Arusha City, Tanzania (2000 – 2015)



Unplanned areas continue to expand (more than planned areas) in Core Area

- Unplanned to planned settlements
- Decrease of unplanned settlements
- Expansion of unplanned settlements
- Expansion of planned settlements
- No change in unplanned settlements
- No change in planned settlements

Mapping of Informal Settlements

Kolkata, India

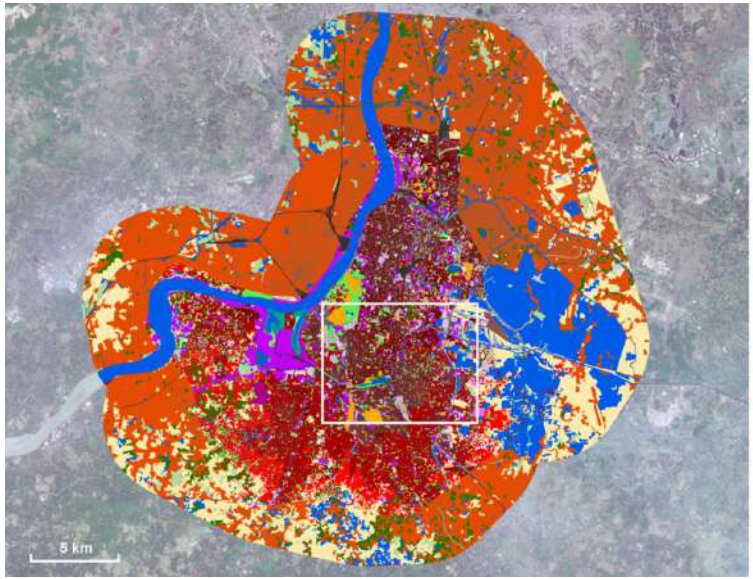
Artificial areas

- Urban / artificial areas
- Formal very high density residential (Sealing level > 80%)
- Formal high density residential (Sealing level: 50% - 80%)
- Formal low density residential (Sealing level: 10% - 50%)
- Informal settlement (Sealing level > 80%)
- Village settlement (Sealing level < 10%)
- Commercial and industrial units
- Non-residential urban fabric
- Roads and associated land
- Railways and associated land
- Port areas
- Airports
- Waste sites
- Construction sites
- Vacant land not obviously being prepared for construction
- Urban greenery
- Sports and leisure facilities

Other types

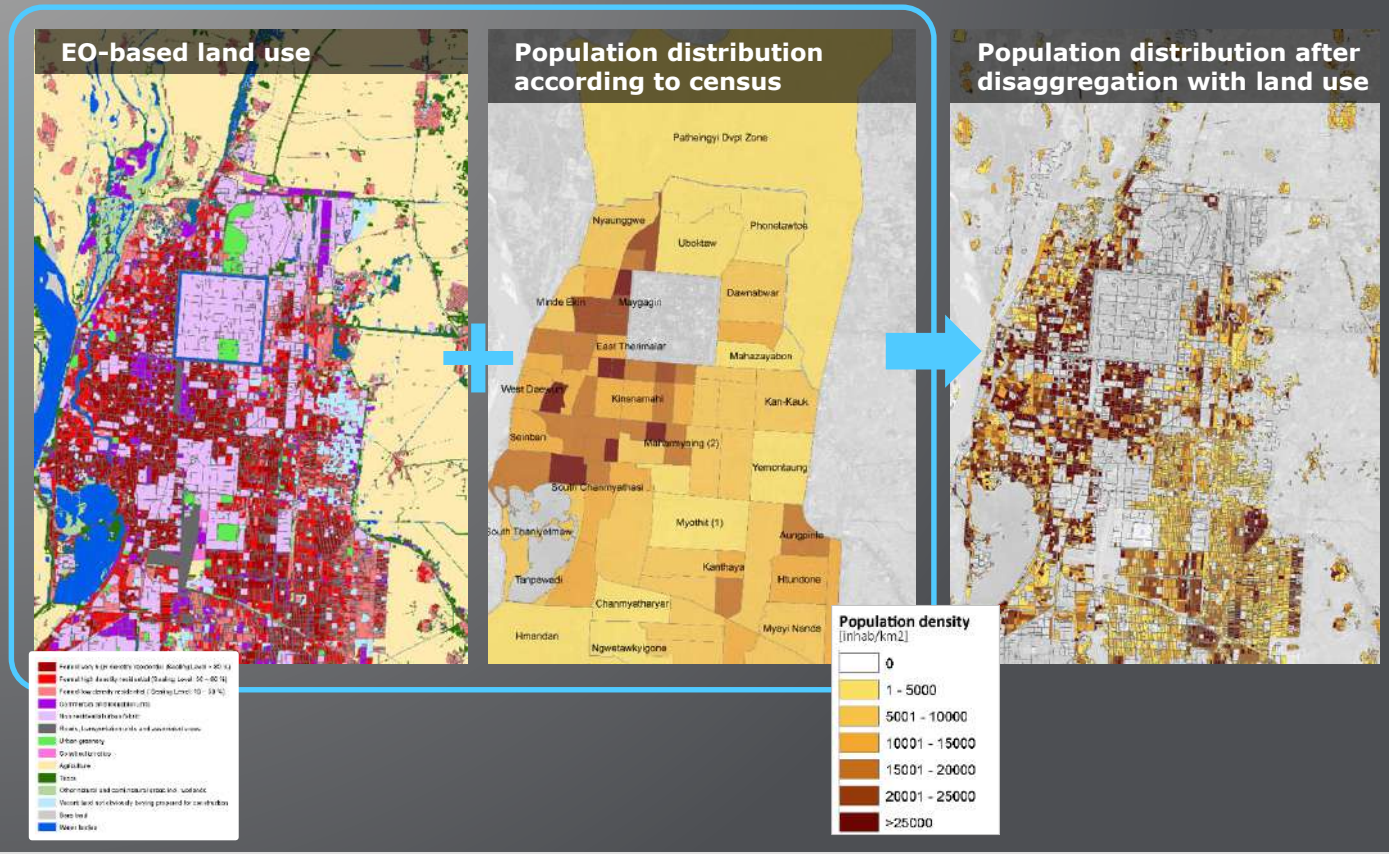
- Agriculture
- Trees
- Other natural and semi-natural areas incl. Wetlands
- Bare land
- Water bodies

Land Use and Land Cover (February–March 2017), based on Pléiades (0.5 m resolution) in the city centre and Sentinel-2 (10 m resolution) for periurban areas



Delineation of informal settlements

Population Distribution Mapping, Mandalay



The spatial distribution of land use types inside each administrative division holds valuable additional information on population distribution.

Knowing the type of urban fabric (residential or nonresidential) allows for further refinement of census data (e.g. work/home, day/night).

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SDG Indicator 11.2.1 Access to public transport

Target 11.2: Transport	**11.2.1:** Proportion of the population that has convenient access to public transport by sex, age and persons with disabilities

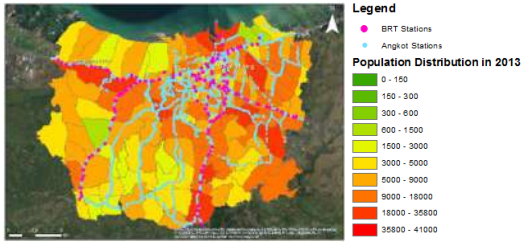
% with access to Public transport = 100x (population with convenient access to Public transport / (City Population))

Input Data:

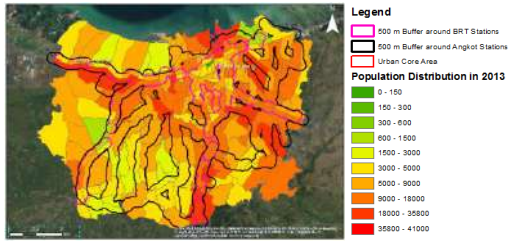
EO4SD-Urban Population Product
Census Data per Ward Level for 2013

Other Spatial Data:

Public Transport Stations (BRT, Angkot)

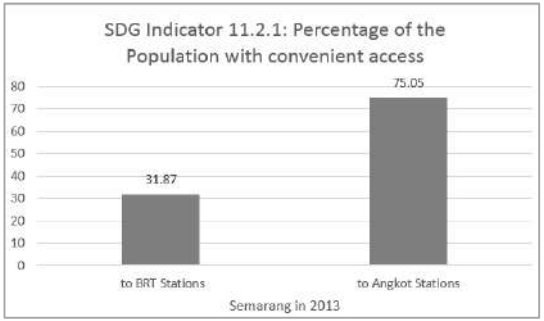


Buffer Analysis:



Semarang, Indonesia

Results:



Population Distribution Mapping based on controlled disaggregation of national census data

Take Home Messages

- **Global Urban Agendas** are calling for cost-effective EO solutions that can help countries worldwide addressing efficiently their development challenges in cities.
- **Copernicus can deliver key environmental information** that supports the definition, planning, implementation, monitoring and assessment of **urban development projects** in particular in developing countries (**data poor countries**).
- **Free and open data policies** of Copernicus program (with **long term continuity** and **frequent revisiting)** bring **unprecedented observations for urban monito**
- **Advances in ICT** (e.g. cloud computing, Machine Learning) allows the genera **global human settlement data sets** from **Sentinels** at affordable prices.
- **Human settlement data** combined with **socio-economic and other inform** to improve understanding of spatial patterns and process banizing world.
- Availability of **on-line platforms** (such as the U-TEP and **in-one" systems** (EO/nonEO data, tools & ICT resources) facilitates adopti s to EO solutions.

Opportunities for an urban component in CLMS Global Land Monitoring Service

Opportunities to stimulate DIAS offerings on urban services (including big data analytics)