High-Resolution Global Monitoring of Urban Settlements

SCERIN–1 Meeting

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German Remote Sensing Data Center (DFD)
Land Surface (LAX)
Urban Area and Land Management Team

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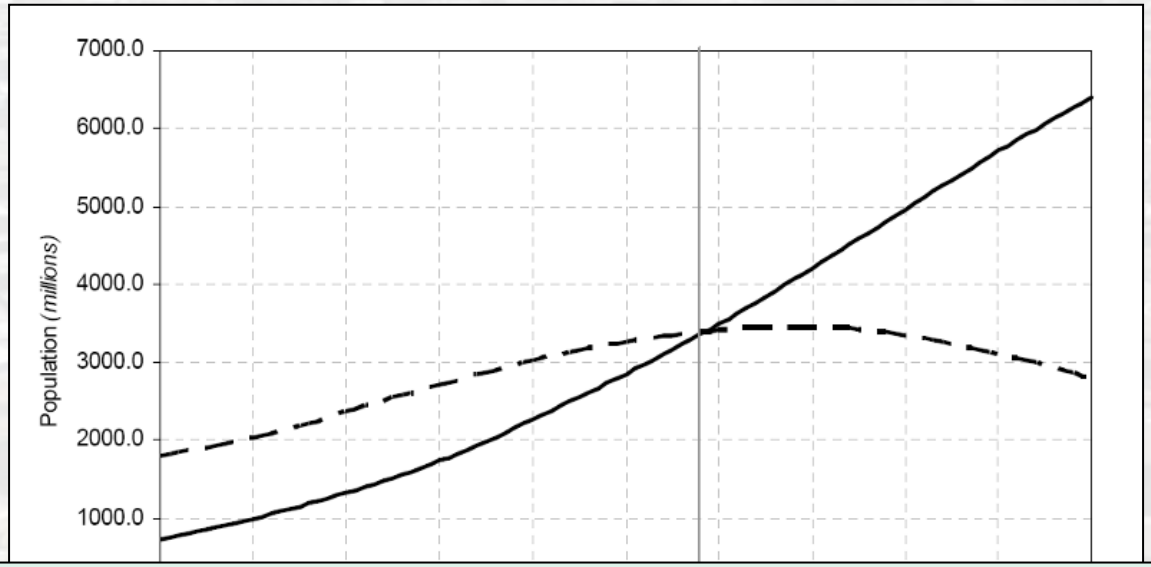
Global Perspective on Human Settlements



- **180.000** additional urban inhabitants per day
- Number of megacities from currently **25** to more than **100** within the next 30 years
- China: **30** new cities with >1 million inhabitants in next two decades
- India: **26** new cities with >1 million inhabitants in next two decades

Planning Times

- For an effective planning it is necessary to reliably know **which is the current extent of urban areas**;

- In **developed countries** cadastral data are generally available [however, it might be sometimes difficult to get all the necessary information when regional (or national planning) has to be investigated];

- In **developing or under-developed countries** often **no official records are available and heavy informal settlement regularly occurs**! (and the population growth here is 6 times faster).

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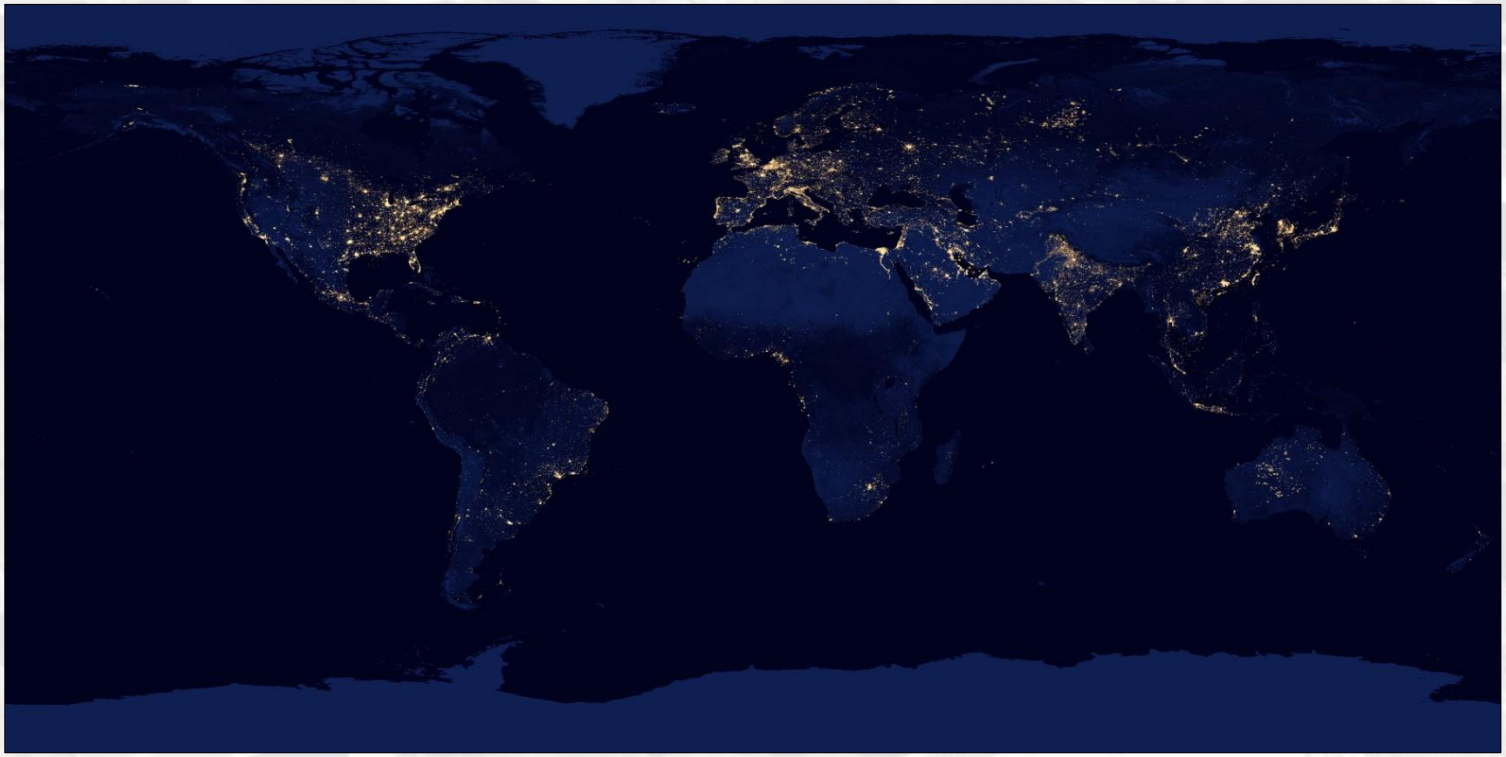
Planning Times

- In the last decade several EO-based and EO-supported **Global Human Settlements Layers (GHSL)** have been produced to map human settlements worldwide.

NASA global nighttime lights product derived from imagery of the Visible Infrared Imaging Radiometer Suite (VIIRS)



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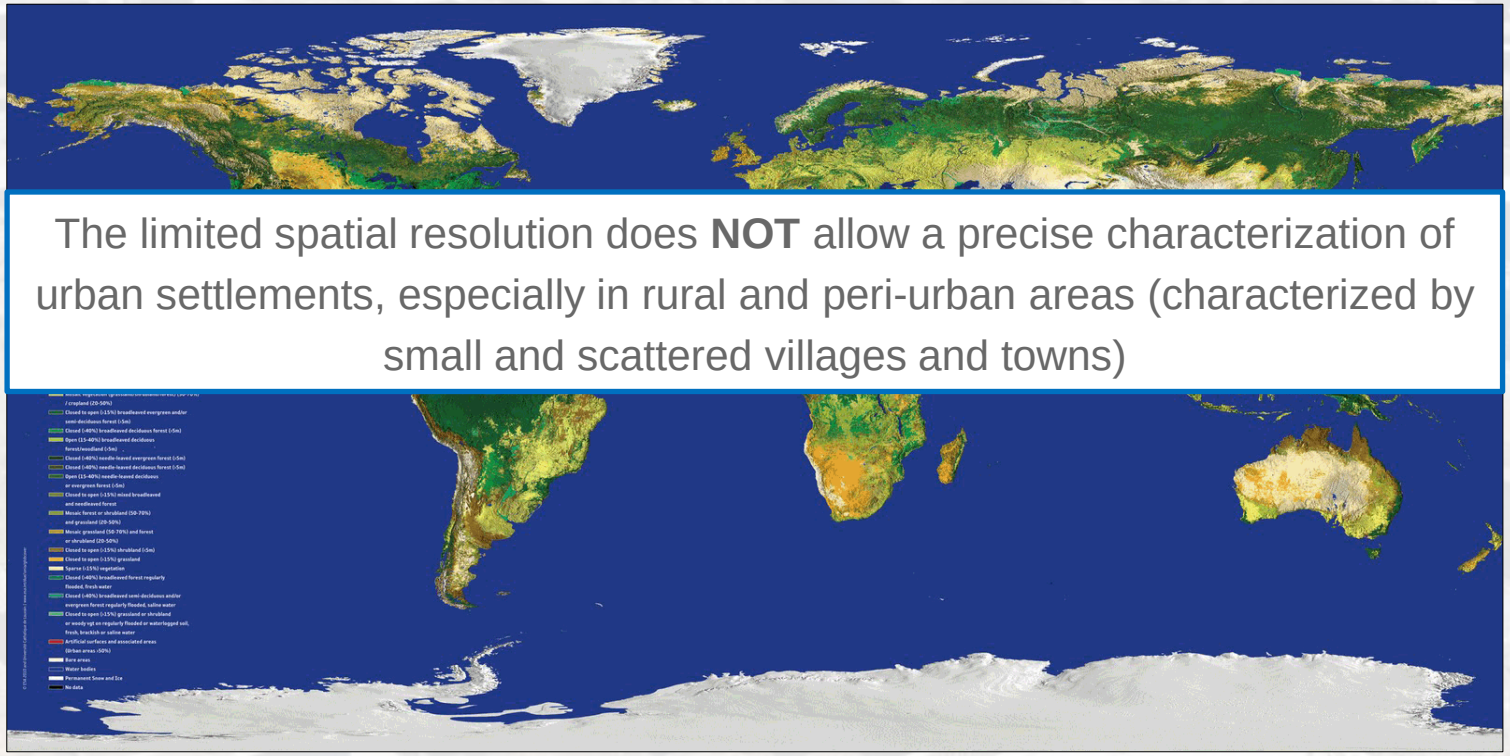
Planning Times

- In the last decade several EO-based and EO-supported **Global Human Settlements Layers (GHSL)** have been produced to map human settlements worldwide.

NASA MODIS 500 (493 m spatial resolution) and **ESA GlobCover 2009** (309 m spatial resolution)



The limited spatial resolution does **NOT** allow a precise characterization of urban settlements, especially in rural and peri-urban areas (characterized by small and scattered villages and towns)

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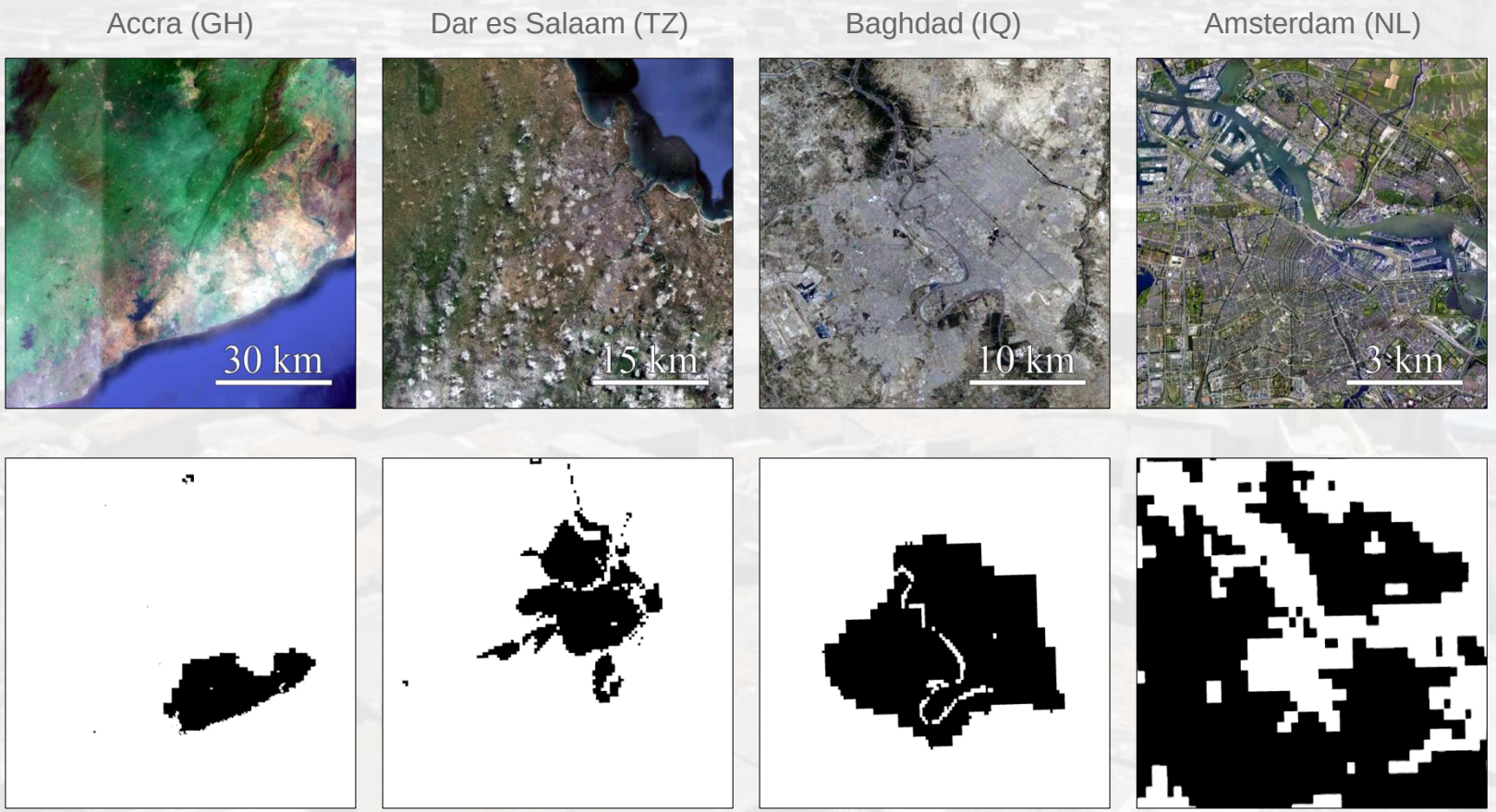
Currently available Global Human Settlements Layers



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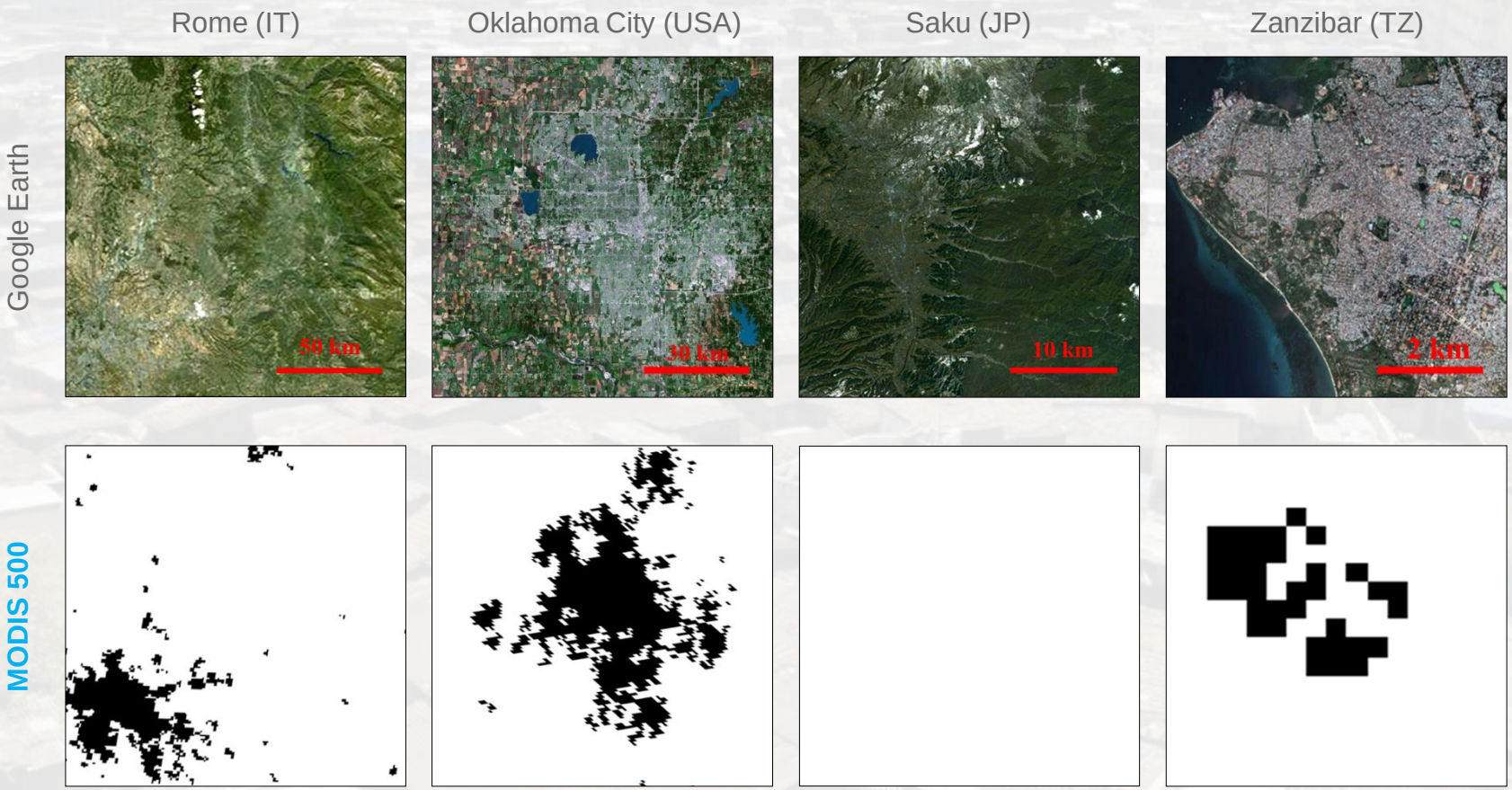
Currently available Global Human Settlements Layers



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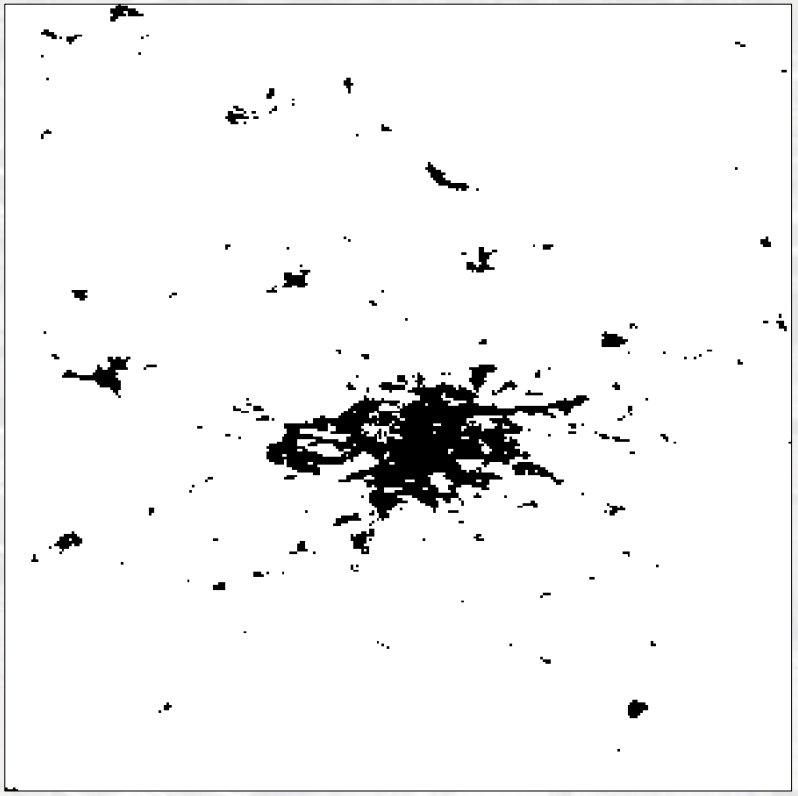
Currently available Global Human Settlements Layers

Prague (CZ)

Google Earth



GlobCover 2009

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Global Urban Footprint

… the next generation GHSL

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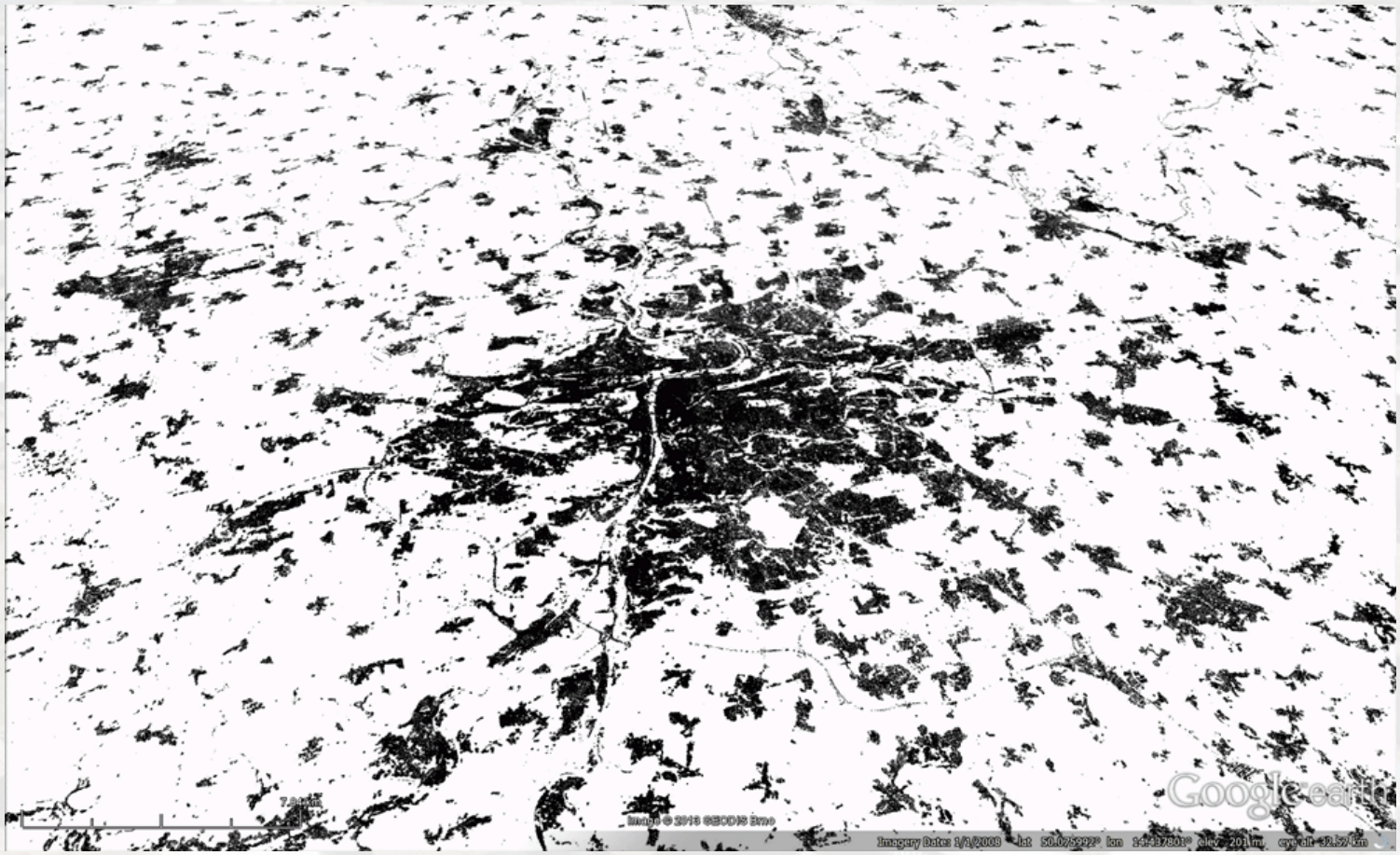
Global Urban Footprint

… the next generation GHSL



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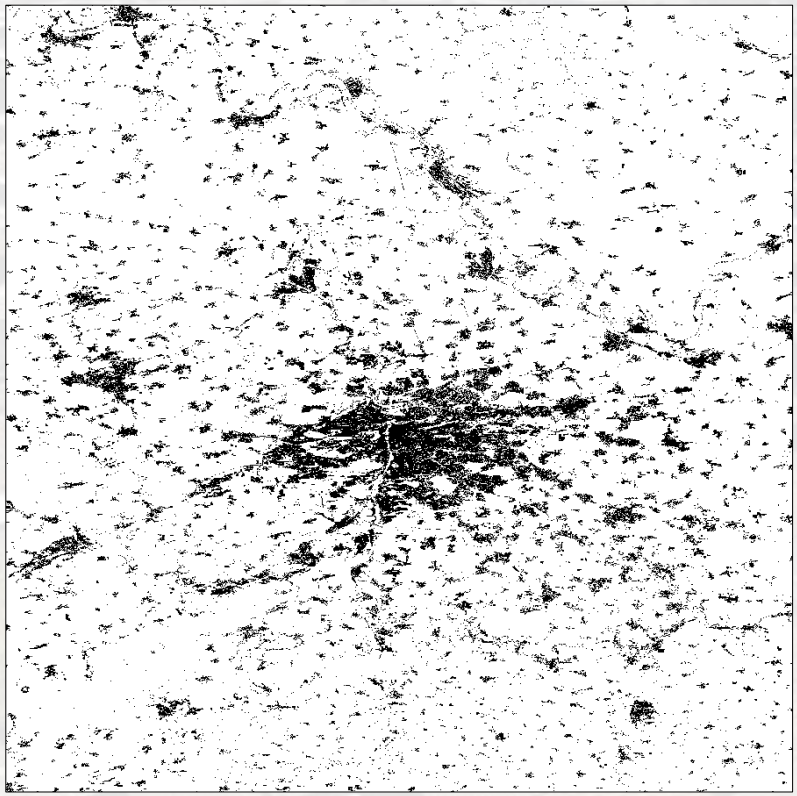
Global Urban Footprint

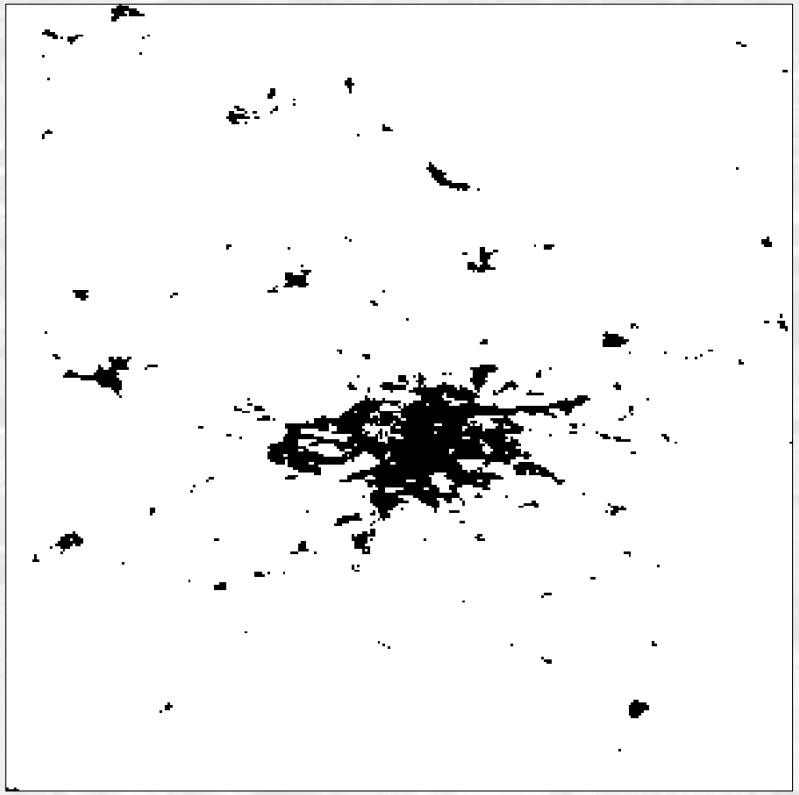
… the next generation GHSL

Currently available Global Human Settlements Layers

Prague (CZ)



Global Urban Footprint



GlobCover 2009

Global Urban Footprint
2011 / 2012

Global Urban Footprint initiative

- World-wide inventory of human settlements using data of TanDEM-X mission;
- Generation of binary settlement masks at VHR;
- Basis for analysis of urban and rural settlement patterns.

Global Urban Footprint
2011 / 2012

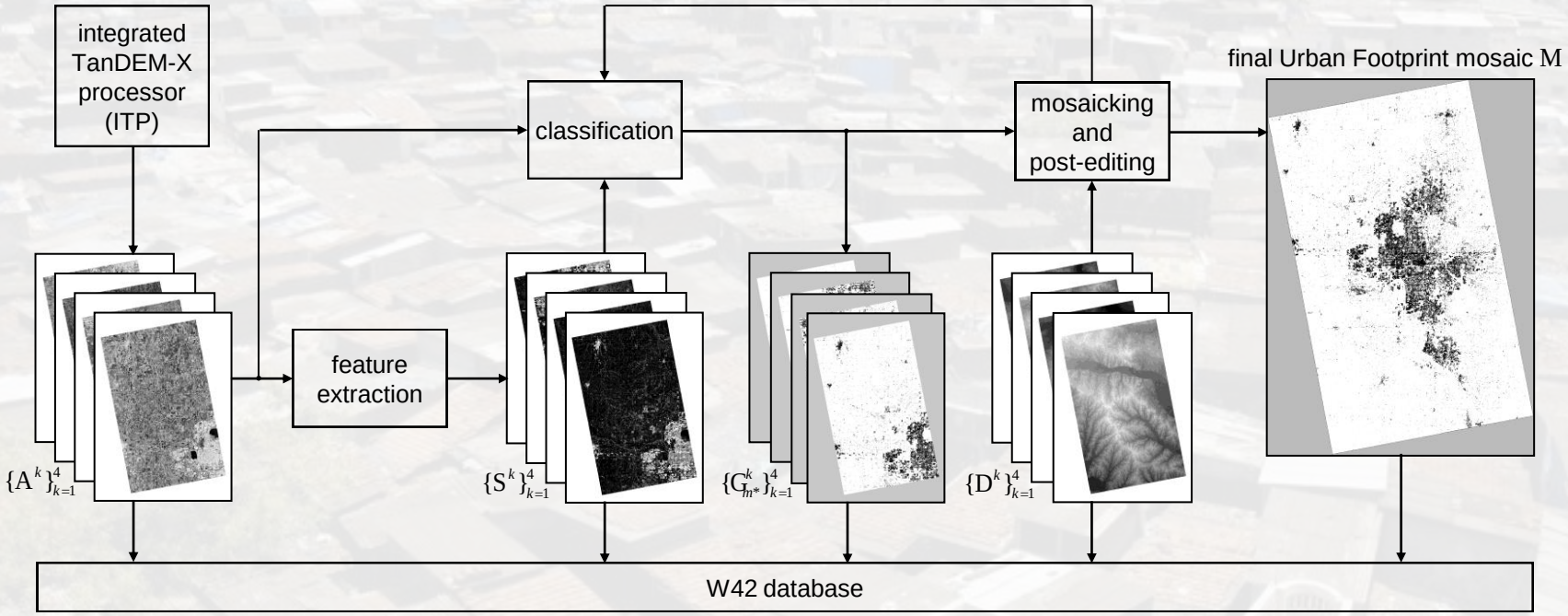
TanDEM-X mission:

- two radar satellites (TSX, TDX)
- global digital elevation model
- image data: ~3 m
- two global coverages (2011, 2012)
- DEM standard products: ~ 12 m

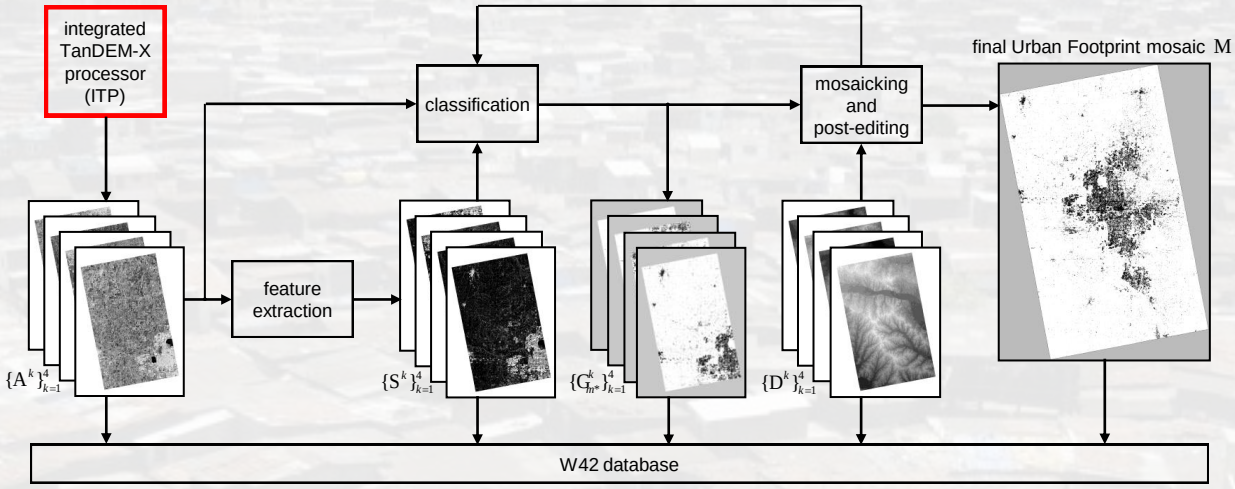
Finalization of Global Urban Footprint layer planned for 2013

Urban Footprint Processor

- The novel fully-automatic processing chain for the production of the GUF is referred to as **Urban Footprint Processor** (UFP):



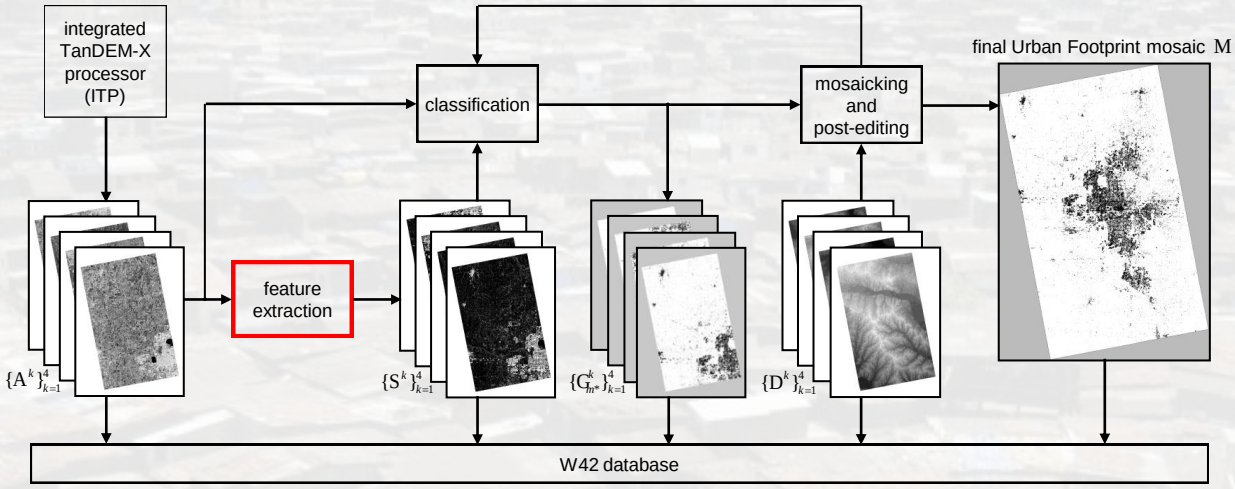
Urban Footprint Processor – Input



- Total number of more than **~180,000 radar images** composing one global TDM coverage (each one with average size of ~50,000 x 45,000 pixels adding up to a final data volume of **~300 TB**);

- SSC images are rescaled to a spatial resolution of about **~0.4 arc sec** (~12 m, i.e., the highest resolution in which the global DEM produced in the context of the TDM will be made available).

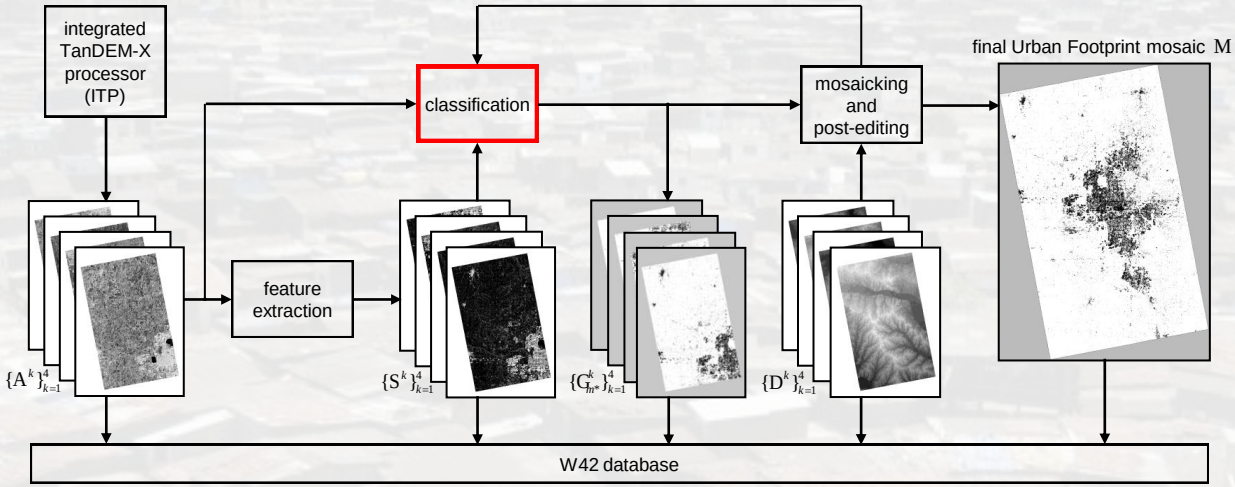
Urban Footprint Processor – Feature Extraction



- The objective of the feature extraction is to derive **effective texture information** for highlighting regions characterized by highly structured and heterogeneous built-up areas;

- To this aim we extract the so-called **"speckle divergence"** feature Σ, which accounts for the specific characteristics of SAR data that exhibit strong scattering due to double bounce effects in urban areas;

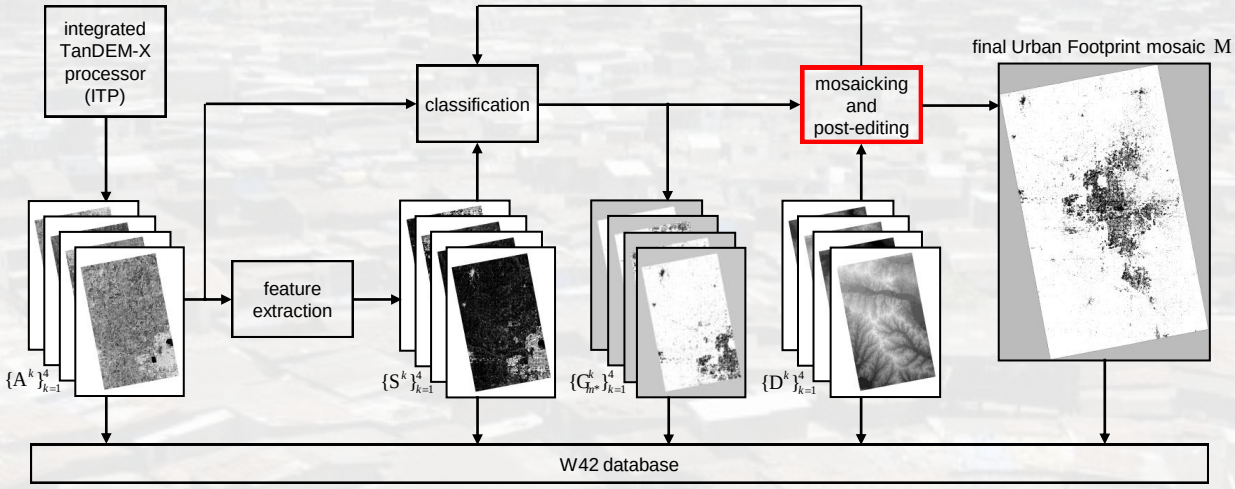
Urban Footprint Processor – Classification



- The aim of the classification stage is to automatically derive a binary settlement layer (built-up, non-built-up) for the investigated scene once provided as input with the backscattering amplitude A and the corresponding speckle divergence Σ;

- To this aim we developed a **novel unsupervised and fully automatic technique** which proved extremely **robust** and **effective**.

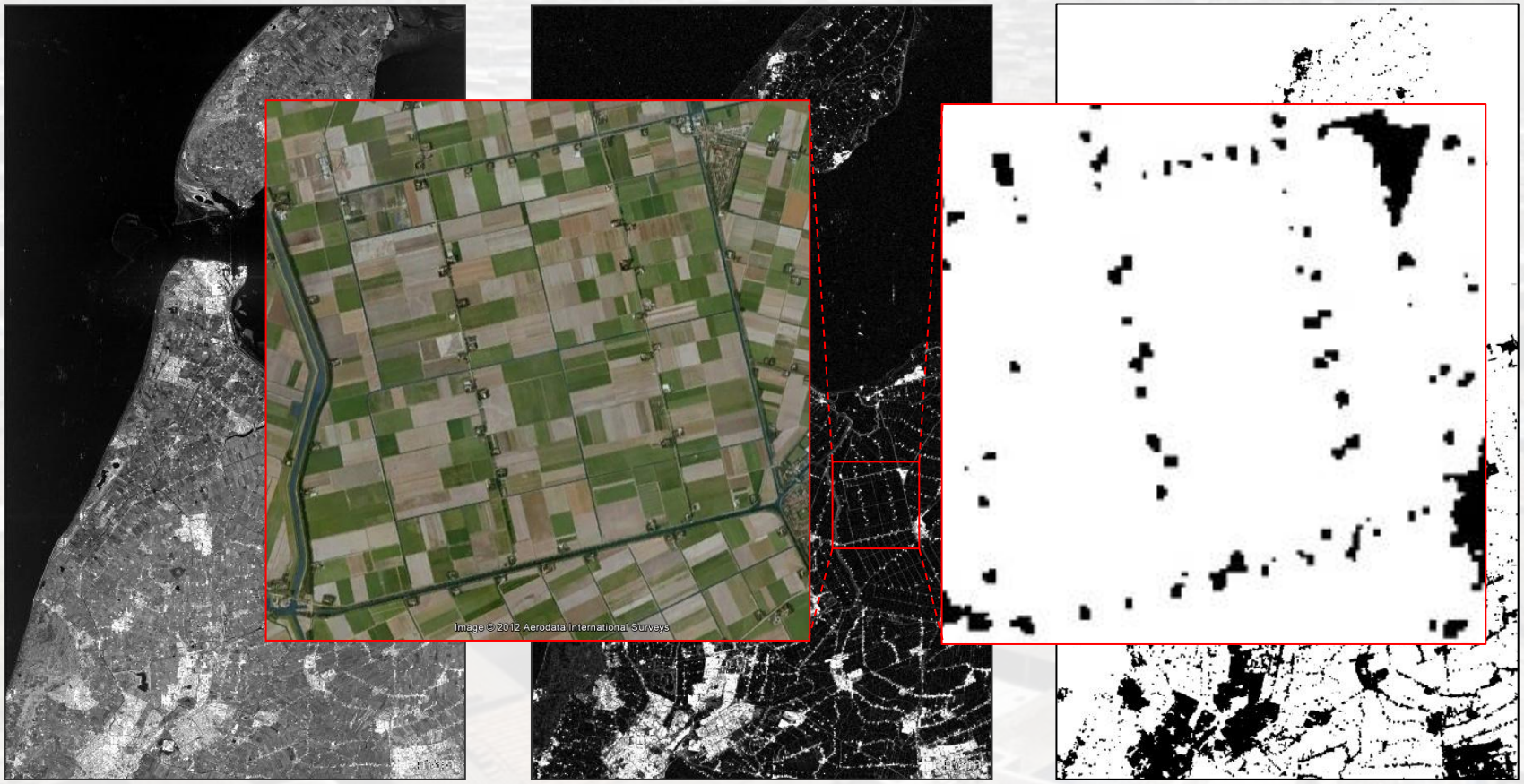
Urban Footprint Processor – Mosaicking and Post-editing



- To overcome overestimation due to topography effects in hilly and mountainous areas, we implemented a dedicated mask derived from the analysis of the ASTER Global DEM.

- In particular, we **mark as non-urban all those pixels whose slope** (intended as the maximum rate of height change between each pixel and its closest eight neighbors) **is higher than 20 degrees in the neighborhood of a local peak**.

Urban Footprint Processor – Classification

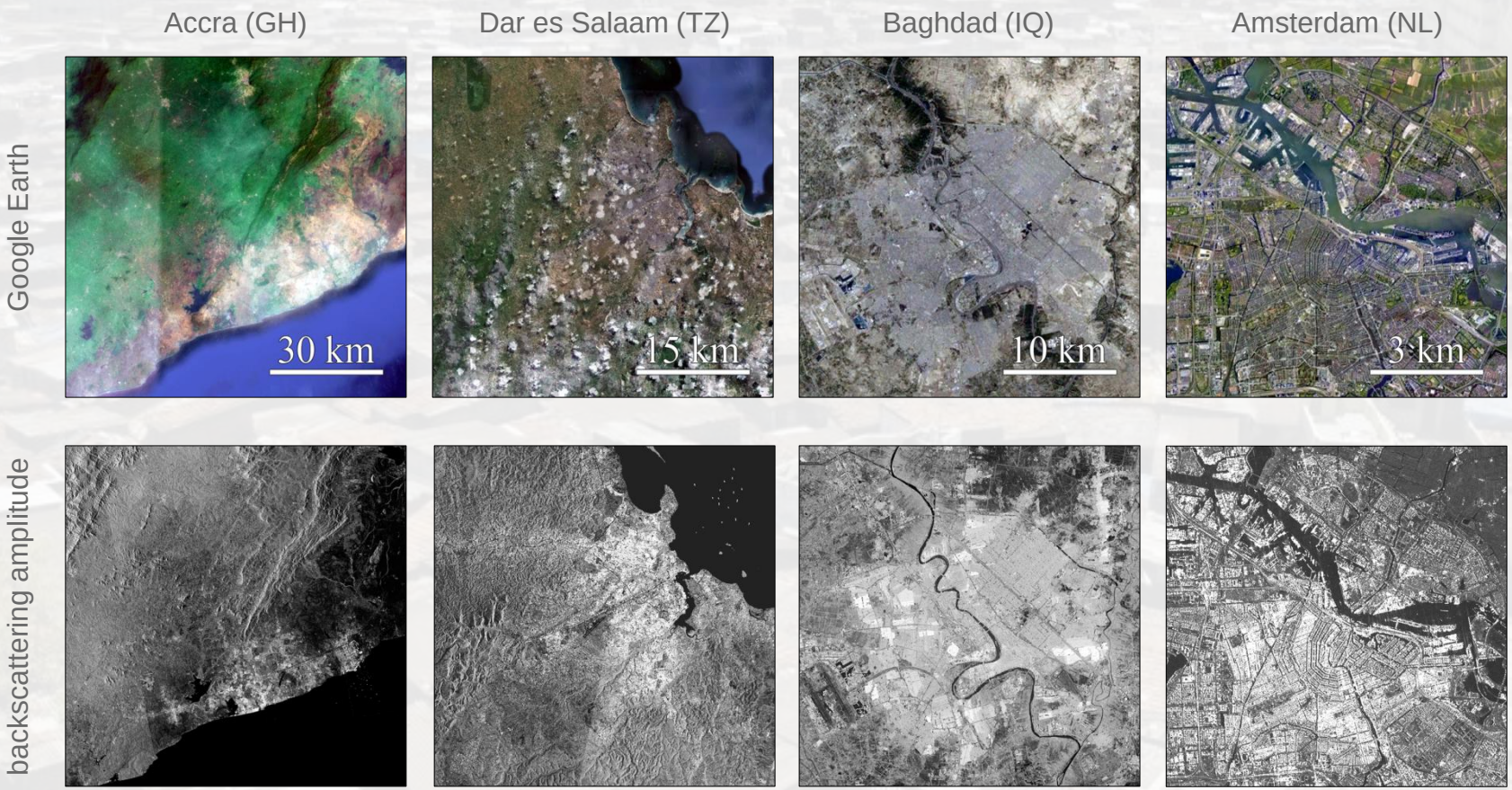


backscattering amplitude

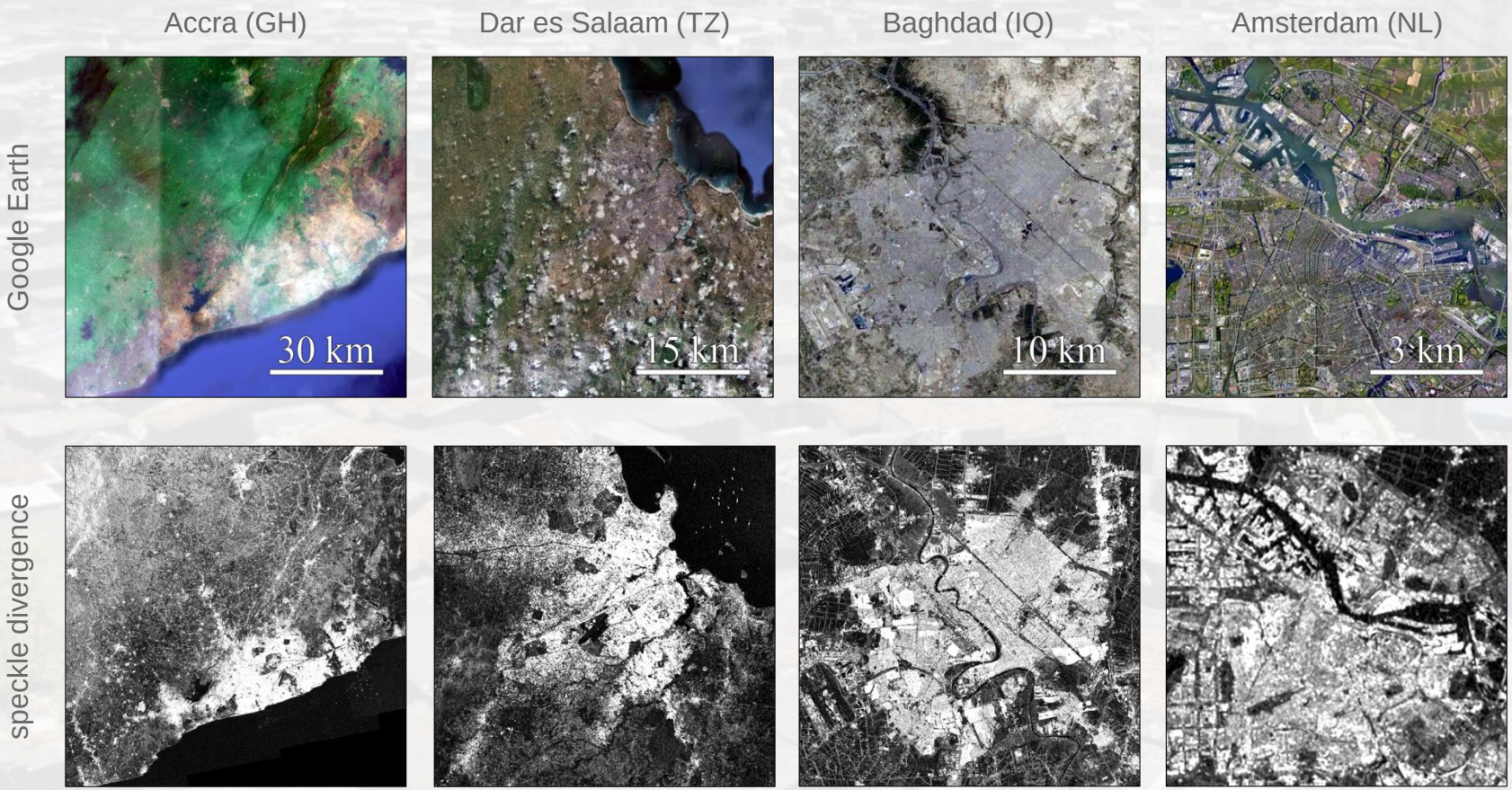
extracted speckle divergence

Global Urban Footprint

Global Urban Footprint vs. GlobCover 2009



Global Urban Footprint vs. GlobCover 2009



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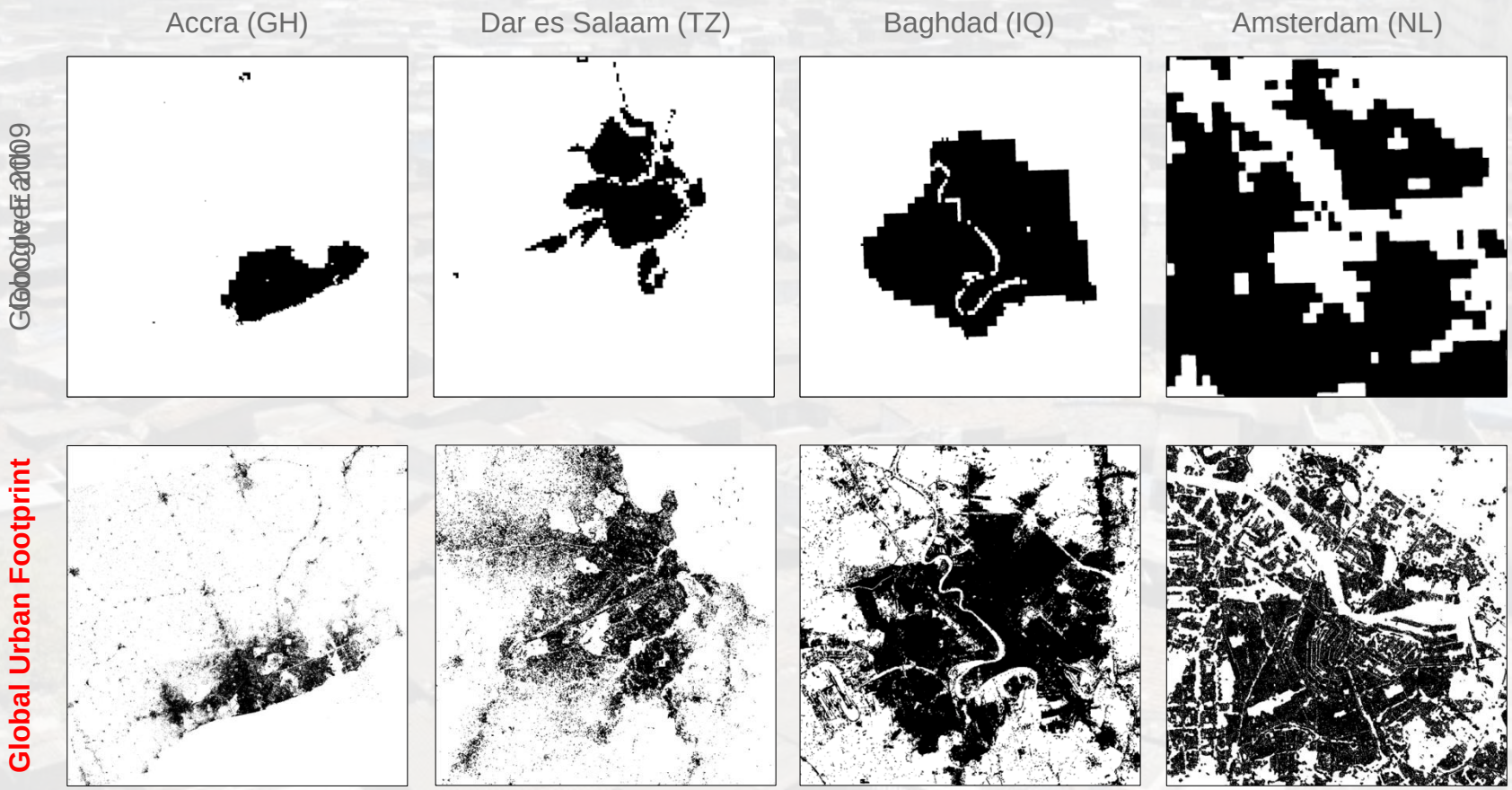
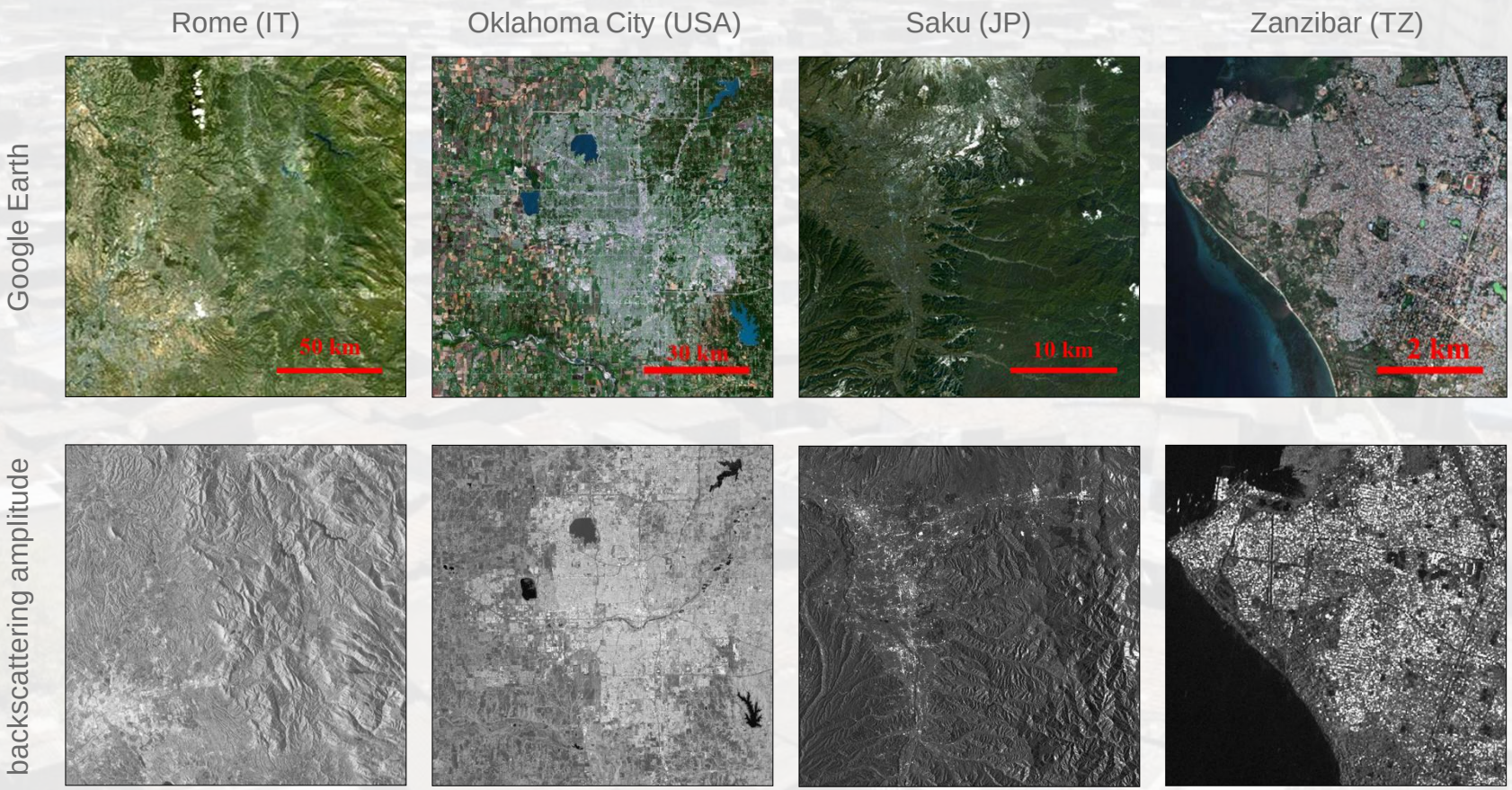


Global Urban Footprint vs. MODIS 500



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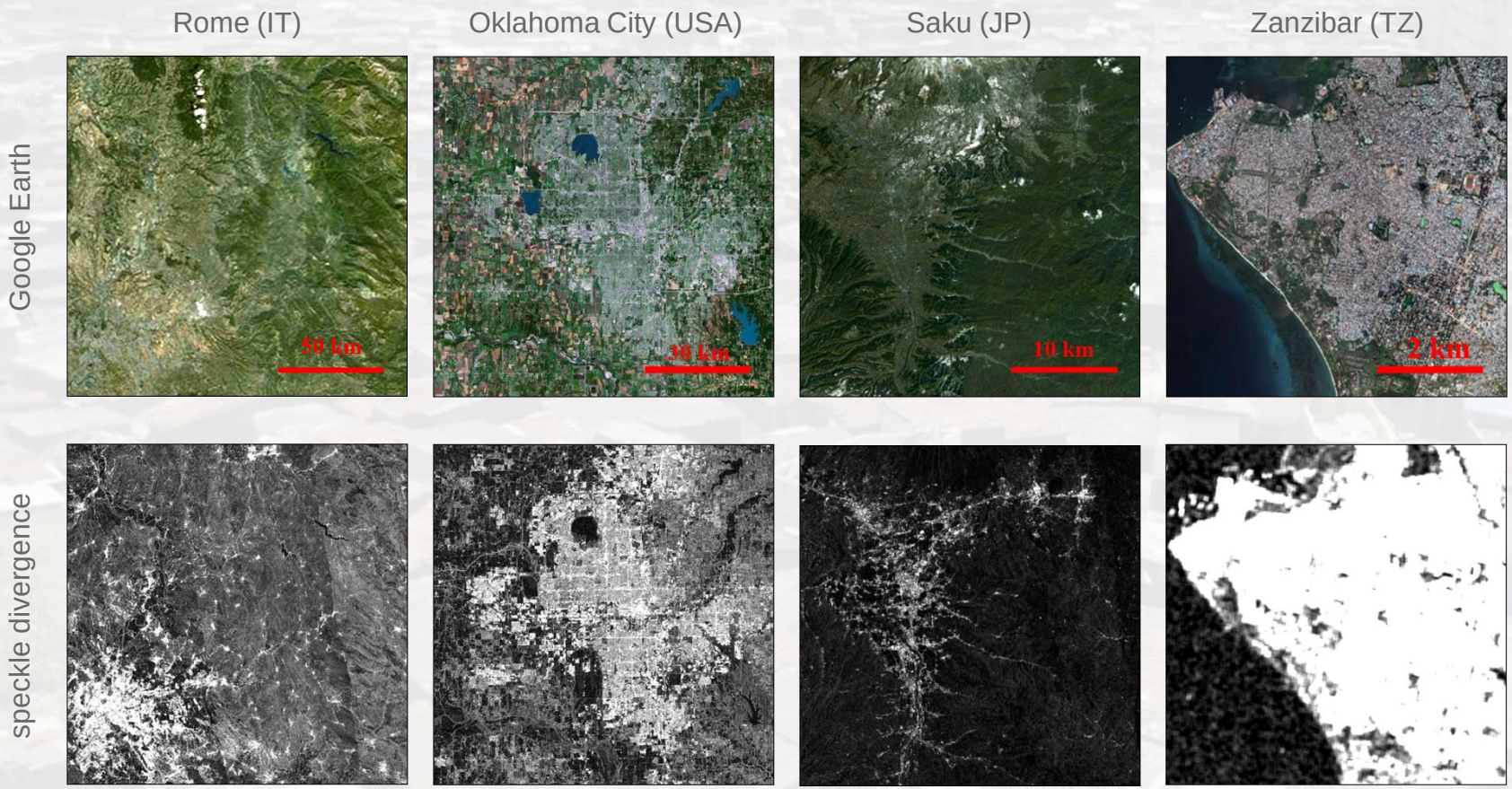
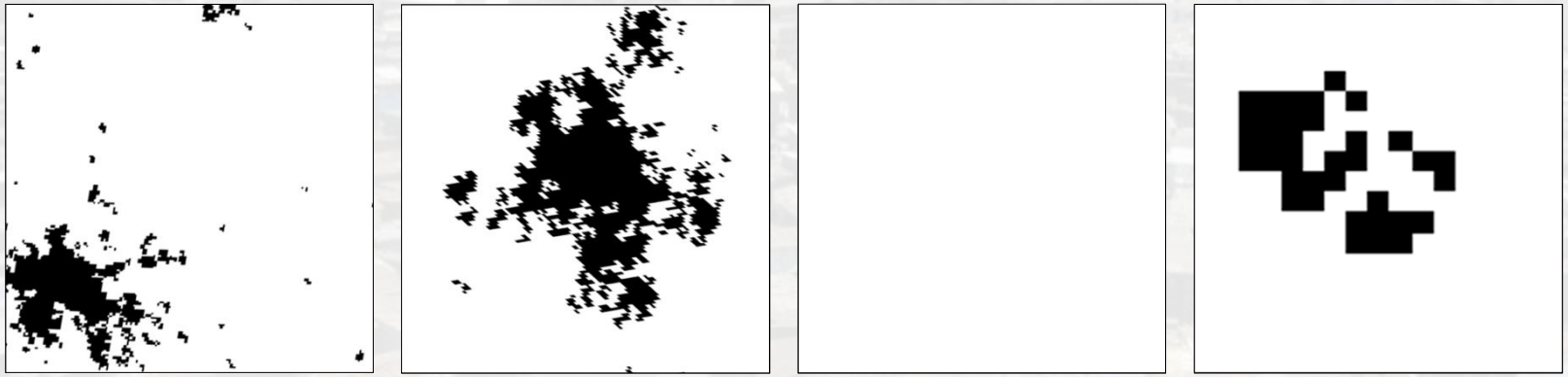


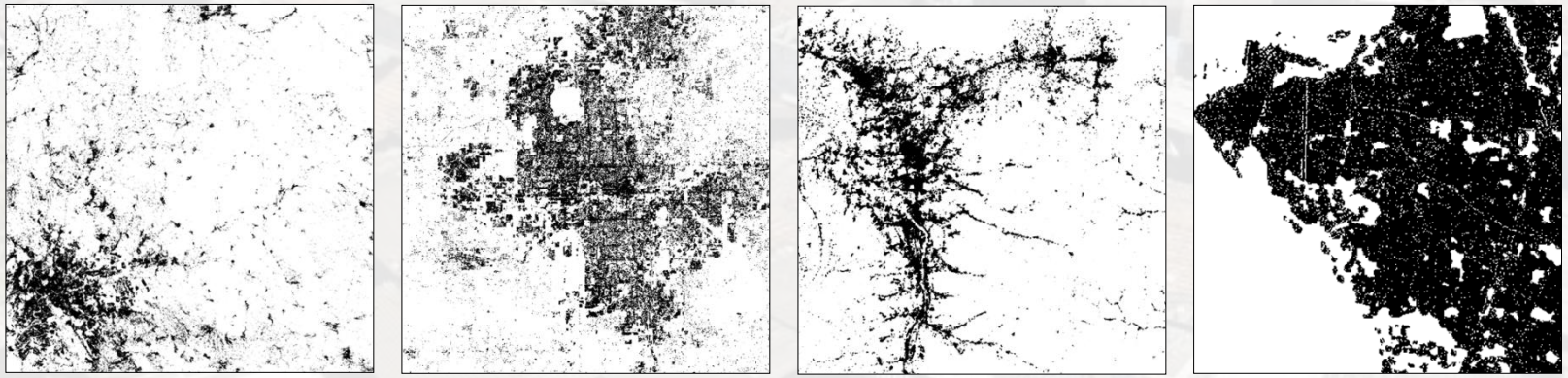
Global Urban Footprint vs. MODIS 500

Rome (IT) | Oklahoma City (USA) | Saku (JP) | Zanzibar (TZ)

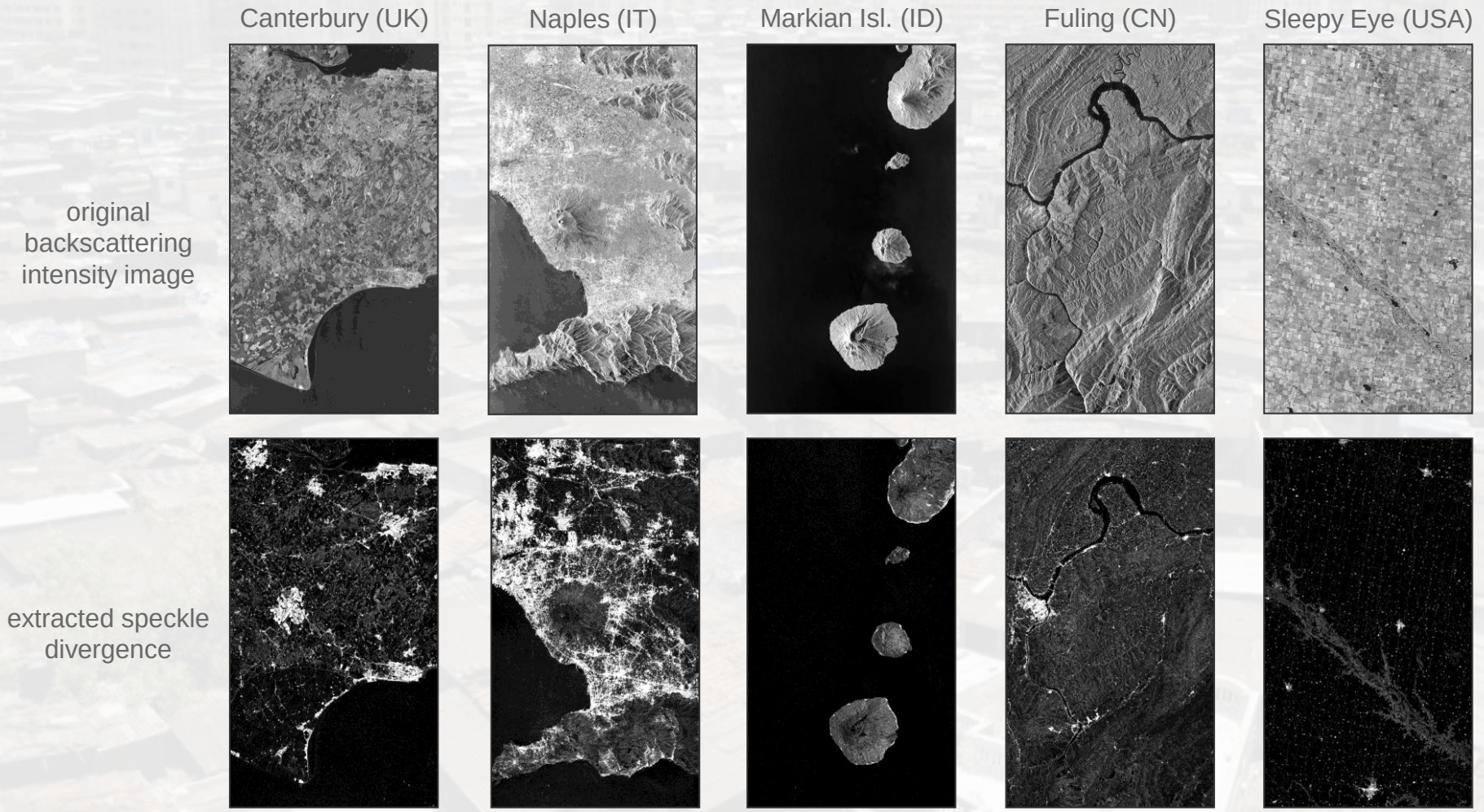
MODIS 500



Global Urban Footprint



Global Urban Footprint – Key Examples



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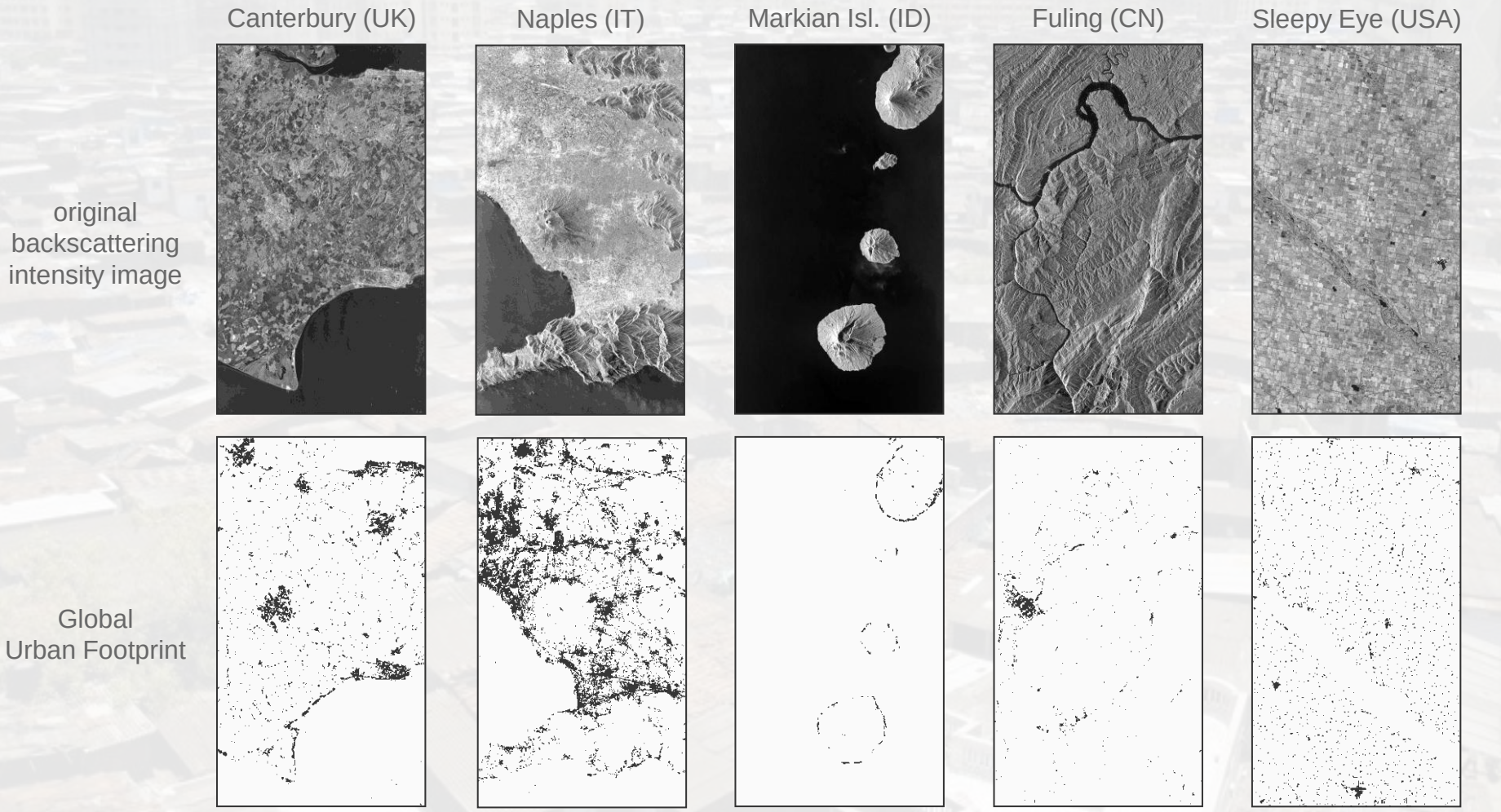
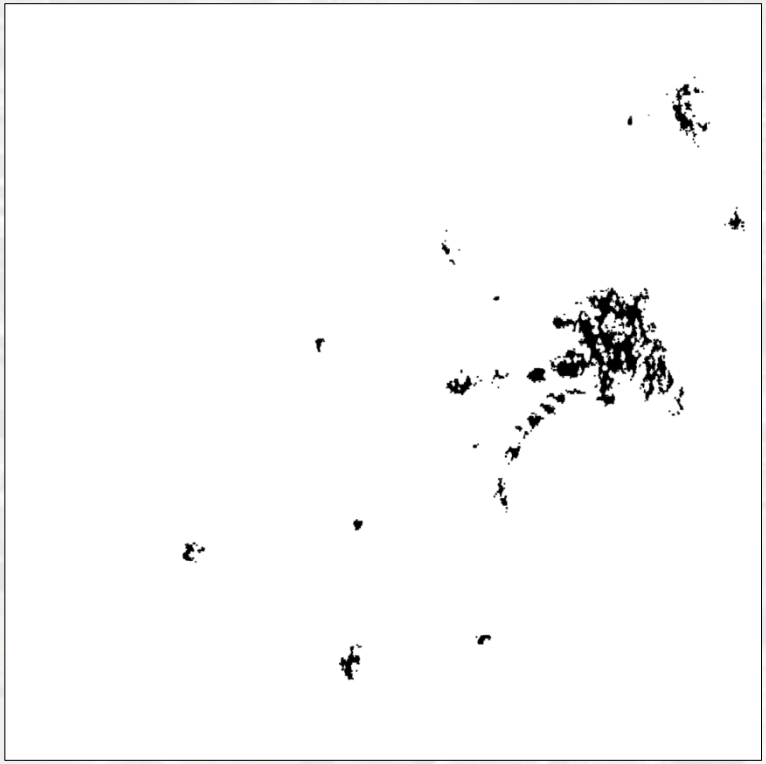


Global Urban Footprint – Zealand (Denmark)

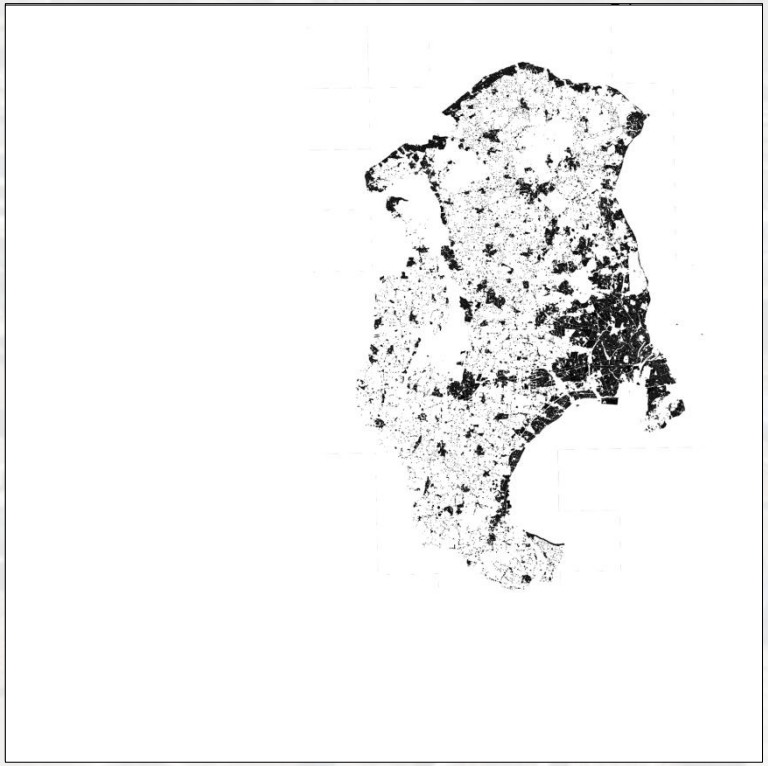
Google Earth



GlobCover 2009

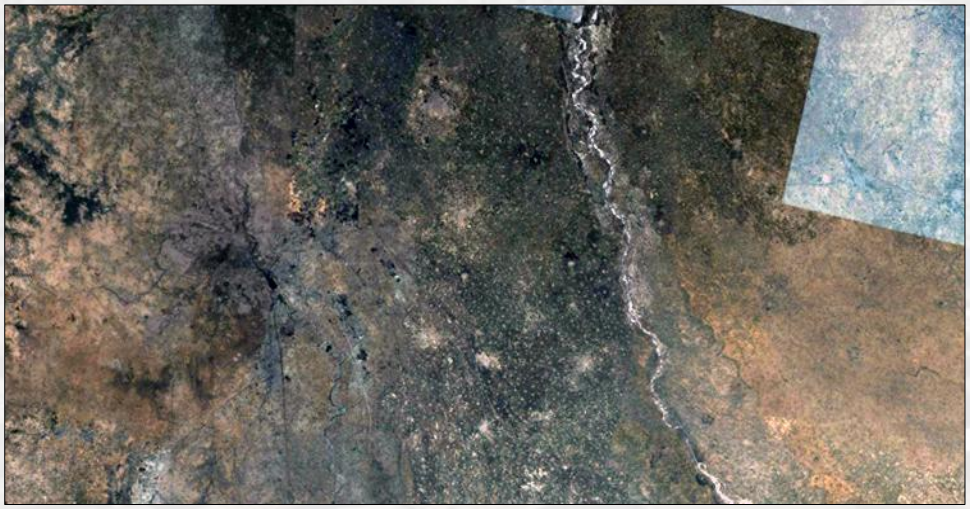
Global Urban Footprint – Zealand (Denmark)

Global Urban Footprint



Global Urban Footprint 2009

Global Urban Footprint – New Delhi (India)



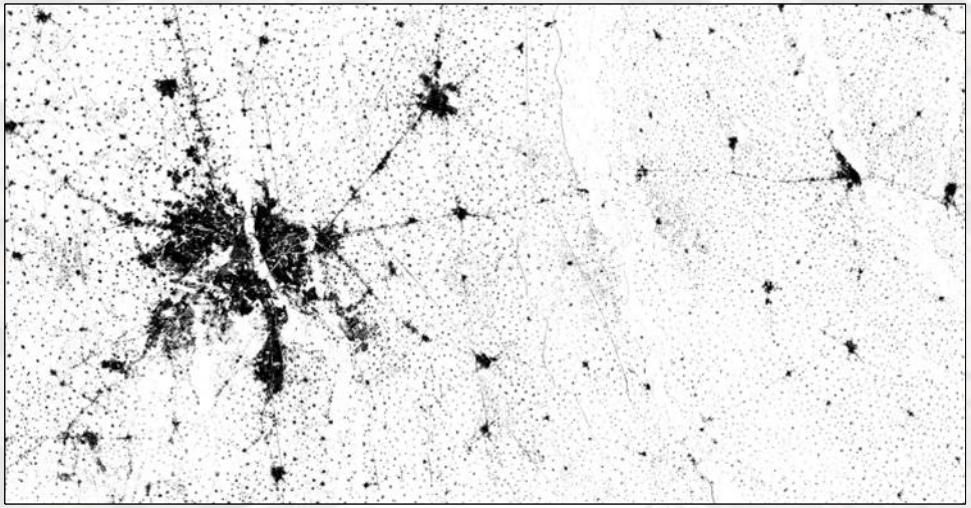
Google Earth

New Delhi Area: **88 images (~90,000 km^2)**

original backscattering amplitude

extracted speckle divergence

Global Urban Footprint



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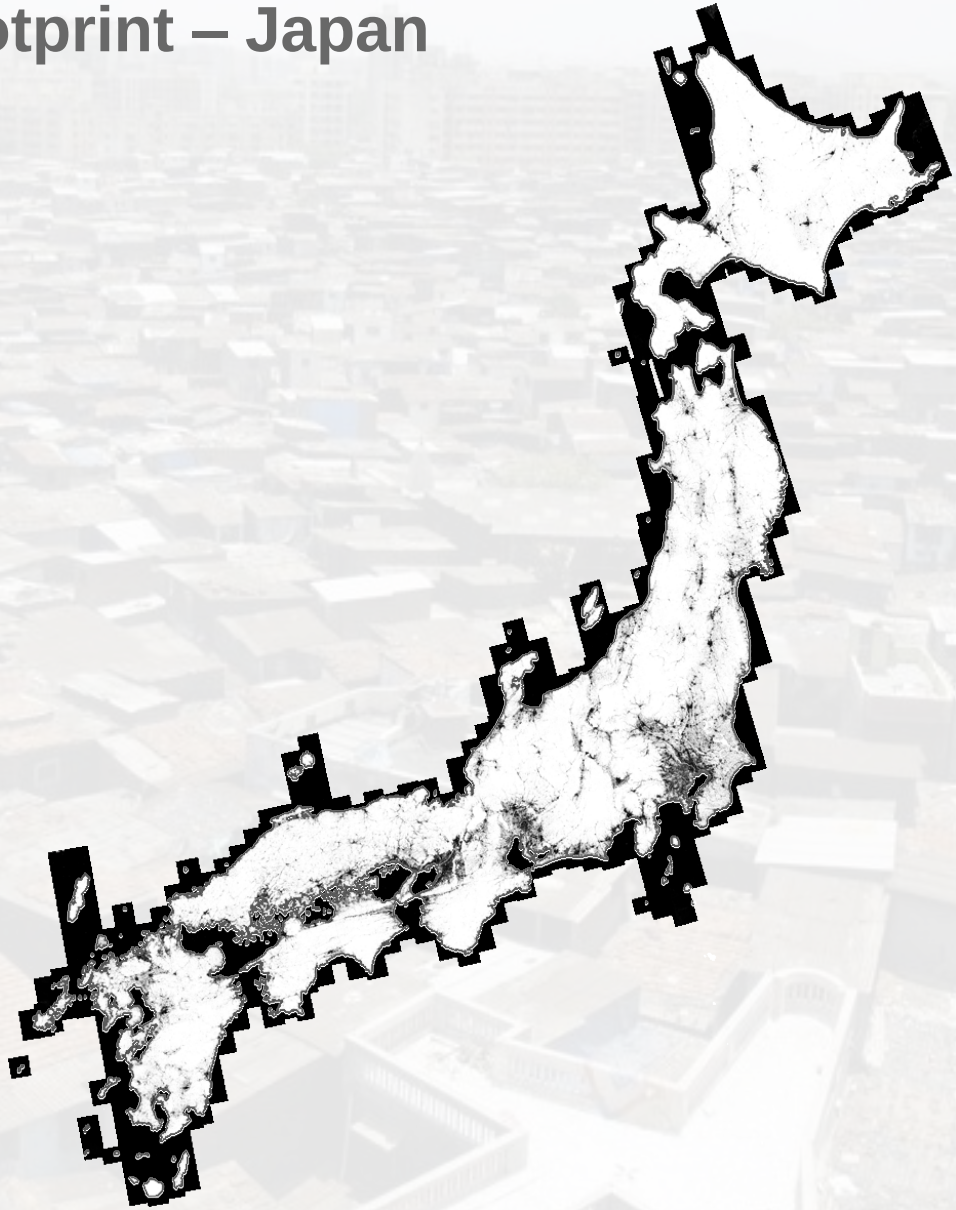
Global Urban Footprint – Japan

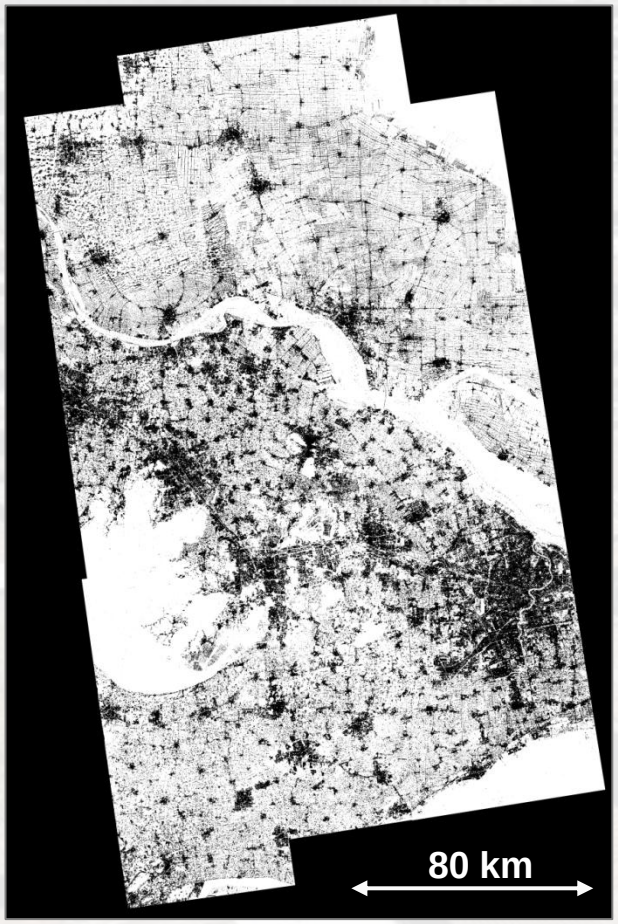


Japan: **~800 images**

original backscattering amplitude

extracted Urban Footprint

Global Urban Footprint – Shanghai (China)



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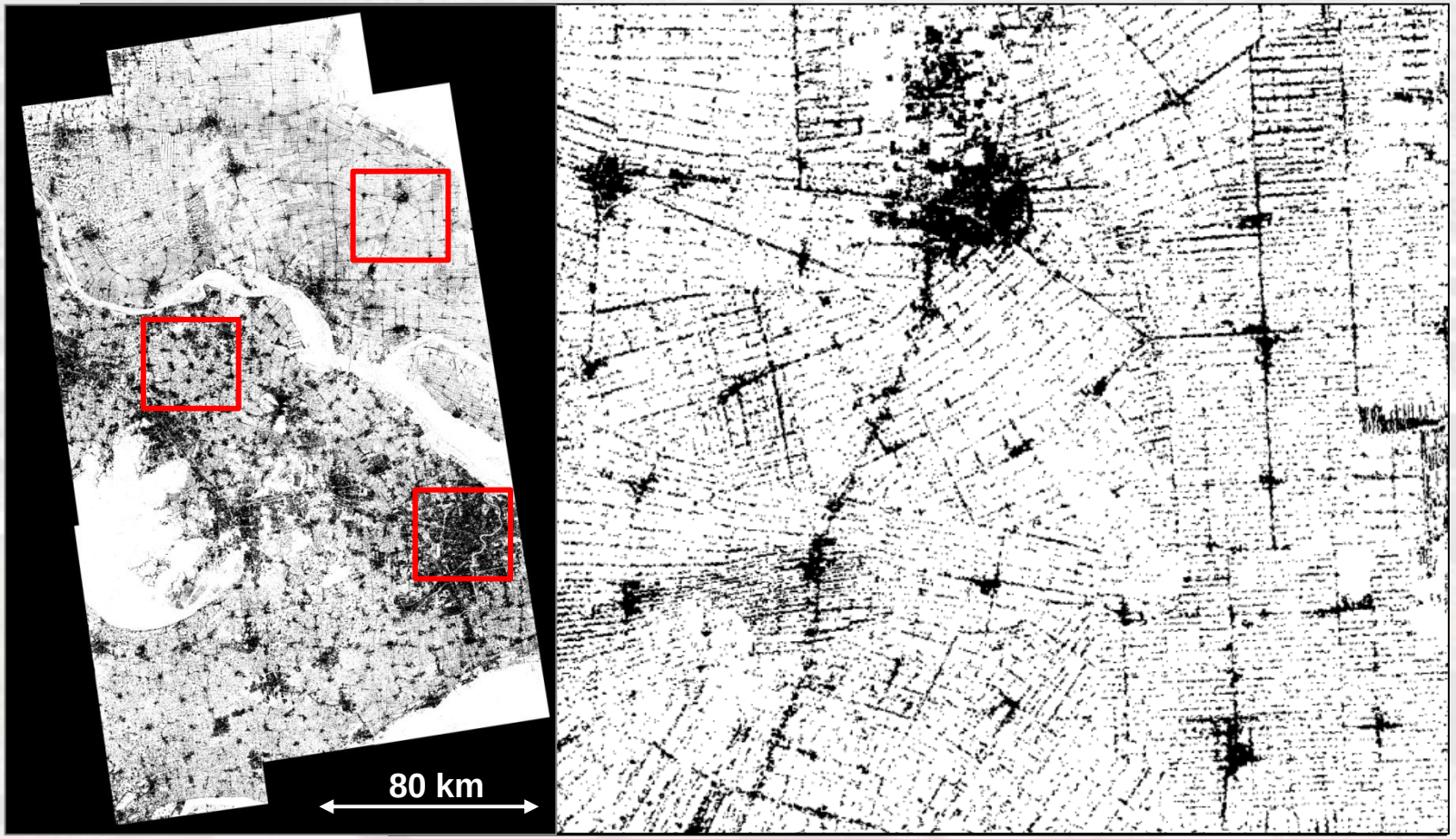
Global Urban Footprint – Shanghai (China)



Urban Footprint

What's next? – Global Urban Growth

Urban spatio-temporal development based on historical optical (Landsat MSS, TM and ETM+) and SAR (ERS, ASAR) data + Global Urban Footprint.

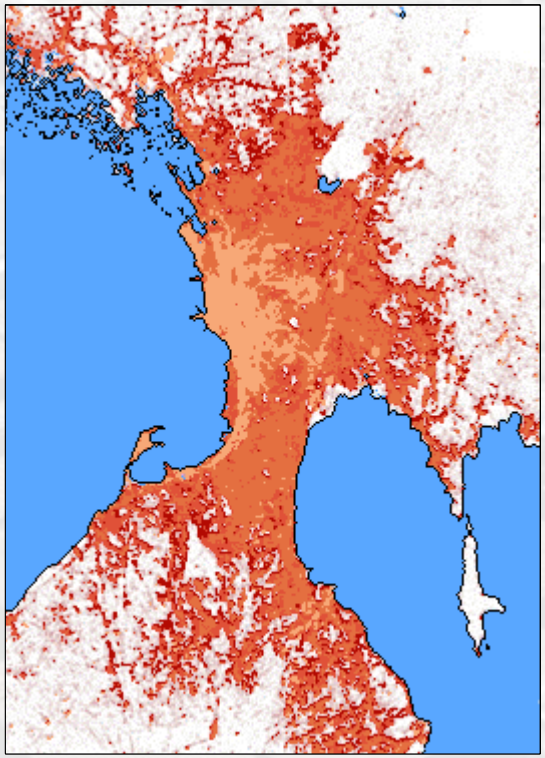
Manila (Philippines)

2010

2000

1990

1975



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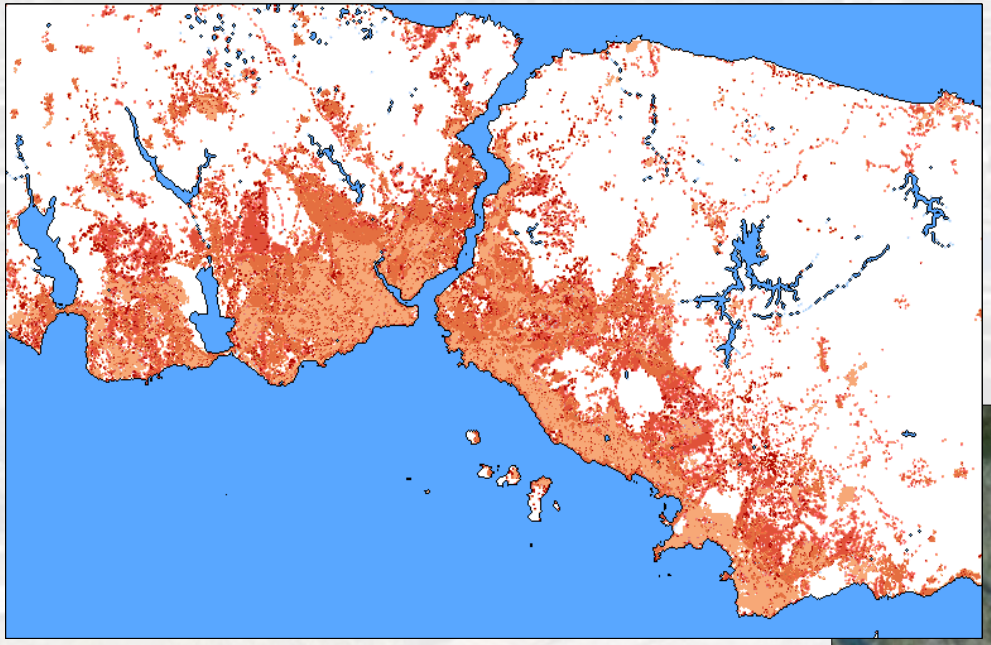

1975 1990 2000 2010

Istanbul (Turkey)

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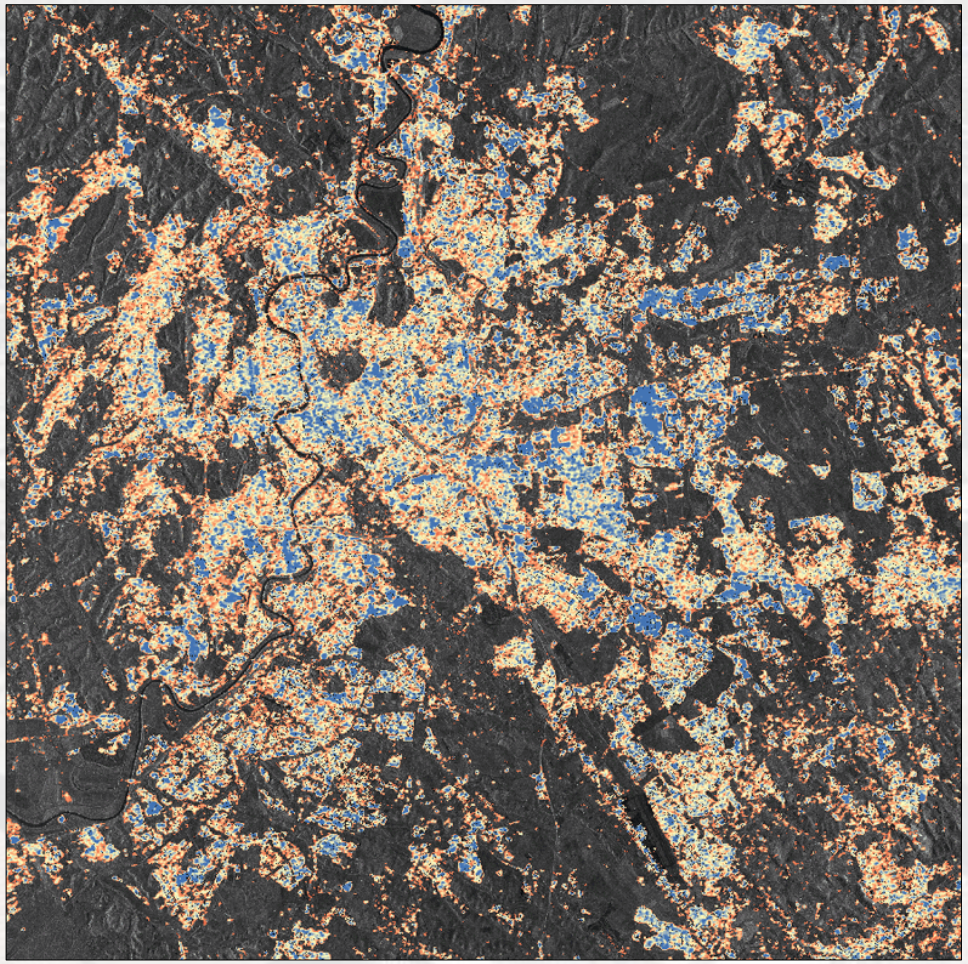
What's next? – Urban Structural Analysis

Estimation of **building density** (concentration of buildings in a given area)

→ key parameter for classification of urban structure types and derivation of building usage



Estimated building density (50x50 m²)

<10% **>80%**

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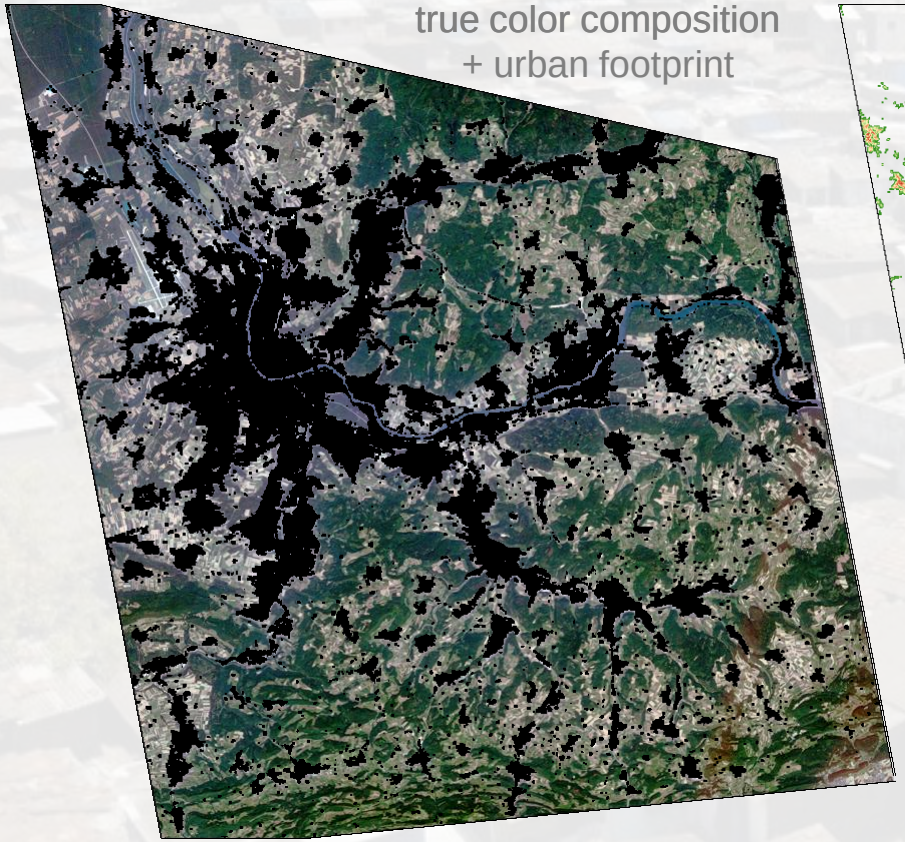
What's next? – Percentage Imperviousness

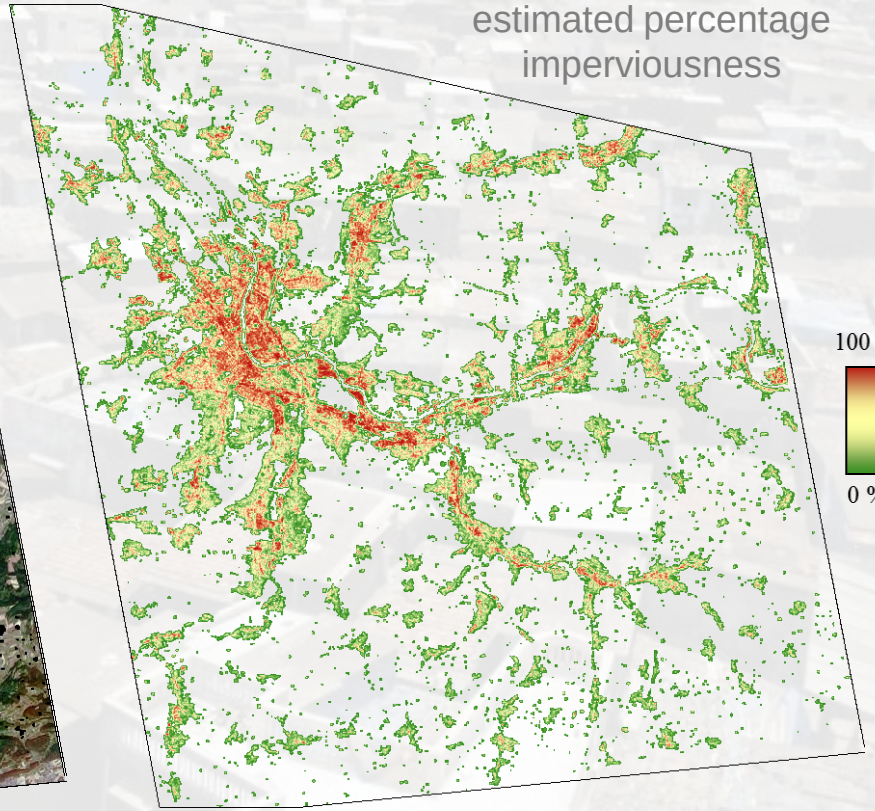
Percentage imperviousness (i.e. percentage of artificial structures covered by impenetrable material) estimated by means of HR optical data (e.g., SPOT, RapidEye) and empirical modelling

Basel (Switzerland) - RapidEye image

true color composition
+ urban footprint



estimated percentage
imperviousness



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What's next? – Building Structure Characterization

Estimated Building Structure (GUF postprocessing)

True Building Structure

What's next? – Building Structure Characterization

Estimated Building Structure (GUF postprocessing)

True Building Structure

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Conclusions

- The presented GUF has already been produced for thousands of images worldwide and preliminary validation results assess its great potential to:
  - support the research into global urbanization patterns;
  - investigate spatiotemporal aspects of (peri-) urbanization;
  - support transdisciplinary and structural analyses.

- Extensive quantitative validation of the GUF based on in situ ground-truth information is ongoing;

- The production of the first GUF layer from the first TDM data coverage is envisaged for 2014 (a public domain version will be made available at ~50-75 m);

- For research purposes it will be possible to access the full-resolution product at 12 m resolution;

- A dedicated website will be online soon.

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… Thanks a lot for your attention! …

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