KTH ROYAL INSTITUTE
OF TECHNOLOGY

EO4Urban: Multitemporal Sentinel-1A SAR and Sentinel-2A MSI Data for Global Urban Services

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ESA DUE Innovator III Program

→ CALL FOR INNOVATORS III

Pioneering innovative Earth Observation products and services for long-term exploitation

deadline for submission of proposals: 29 August 2014

Open to ALL domains of EO applications and ALL fields of the Earth's atmosphere, ocean, cryosphere and land surfaces.

Innovators III priority lines:

- Respond to the **Research and Development agenda** of major international initiatives e.g. GEO
- perform the necessary R&D preparatory activities of the most innovative aspects of **Sentinel-1** and **Sentinel-2**, for a large scale exploitation by broad user communities.

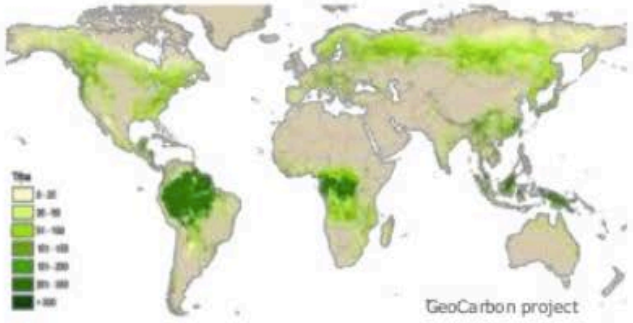
AO 7829	
ITT issue:	14 May 2014
KO:	Q4 2014
Contracts:	12 up to 200 k€
Overall budget:	€2,400,000
Duration:	max. 2 years

Innovators III will contribute to the content of ESA EOEP-5 (2017-2021)

European Space Agency

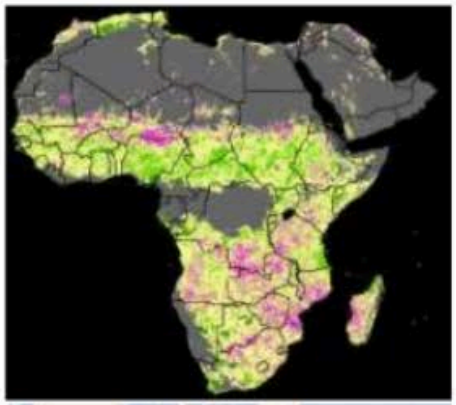
DUE Opportunities

GLOBBIOMASS



ITT issued:	15 May 2014
KO:	Q3 2014
Budget:	€1,500,000
Duration:	3 years

GLOBWETLAND AFRICA



ITT issue:	Q3 2014
KO:	Q4 2014
Budget:	€1,500,000
Duration:	3 years

DUE PERMAFROST

ITT issue:	Q4 2014
KO:	Q1 2015
Budget:	€1,000,000
Duration:	3 years

European Space Agenc

ESA DUE Innovator III Projects

innovators eoforurban **Global Urban Services**

Team	KTH Royal Institute of Technology, Sweden
	University of Pavia, Italy
Users	Stockholm County Administrative Board, Sweden
	National Geomatics Center, China

innovators sarforurban Urban monitoring

innovators eoforcbi City Biodiversity Index

ESA DUE Innovator III Projects

innovators smart — Aquaculture management

innovators georice — Rice monitoring

innovators accucarbon — Forest Carbon Prediction

innovators formosa — Forest degradation

innovators sarforredd — Forest mapping

innovators rsforebv — Essential Biodiversity Variables

innovators smells — Early warning of desert locust

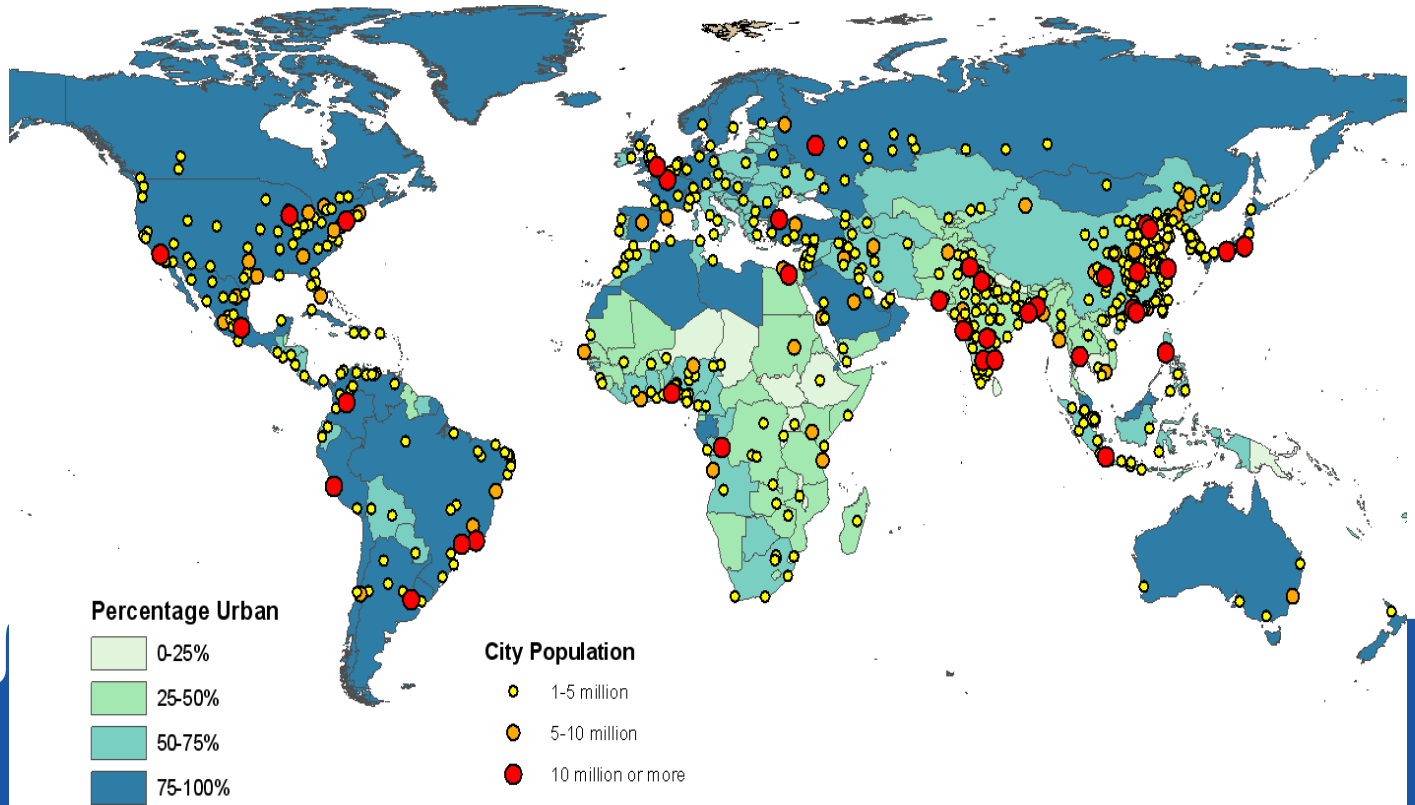
innovators vecborn — Vector borne diseases management

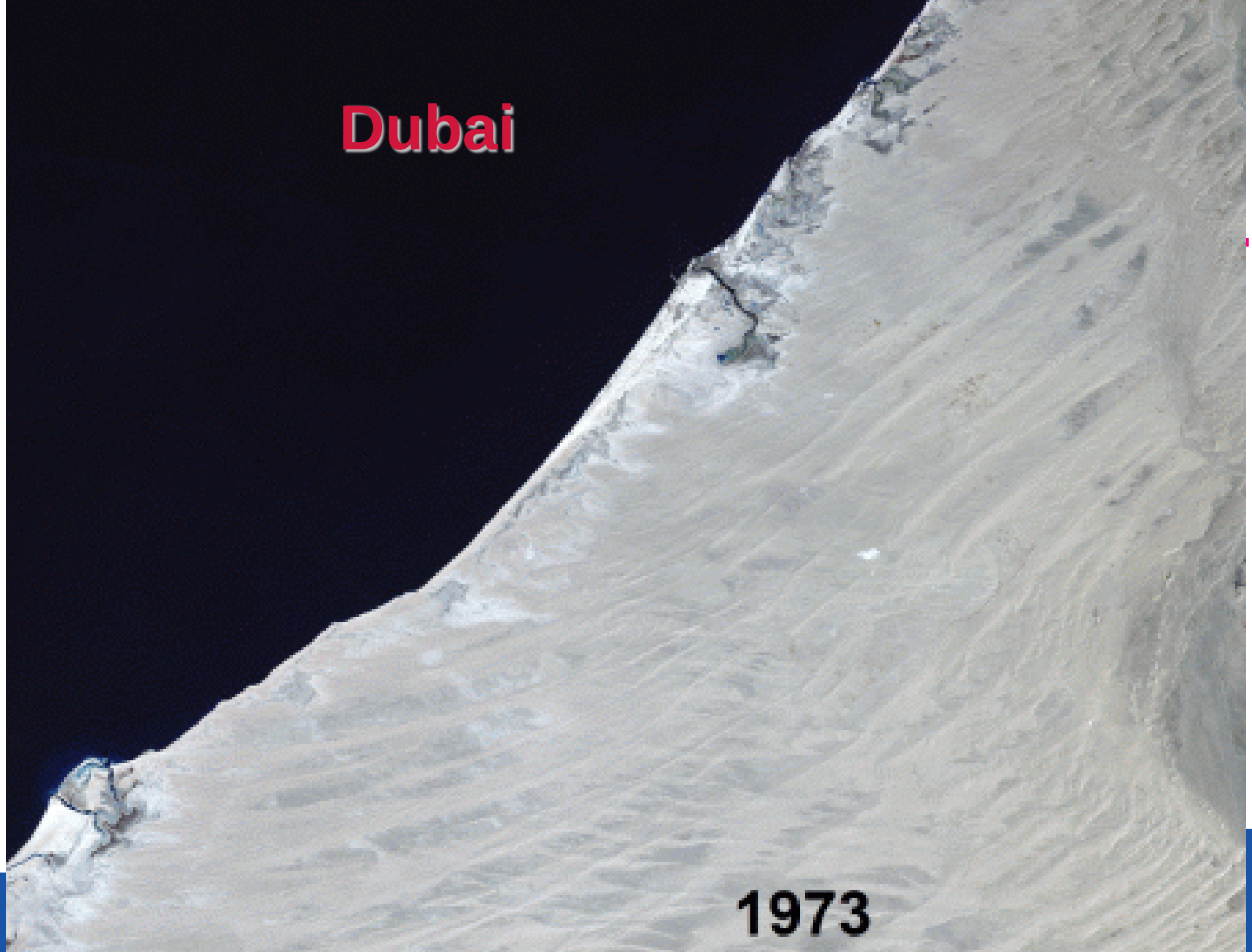
innovators sponge — Water monitoring

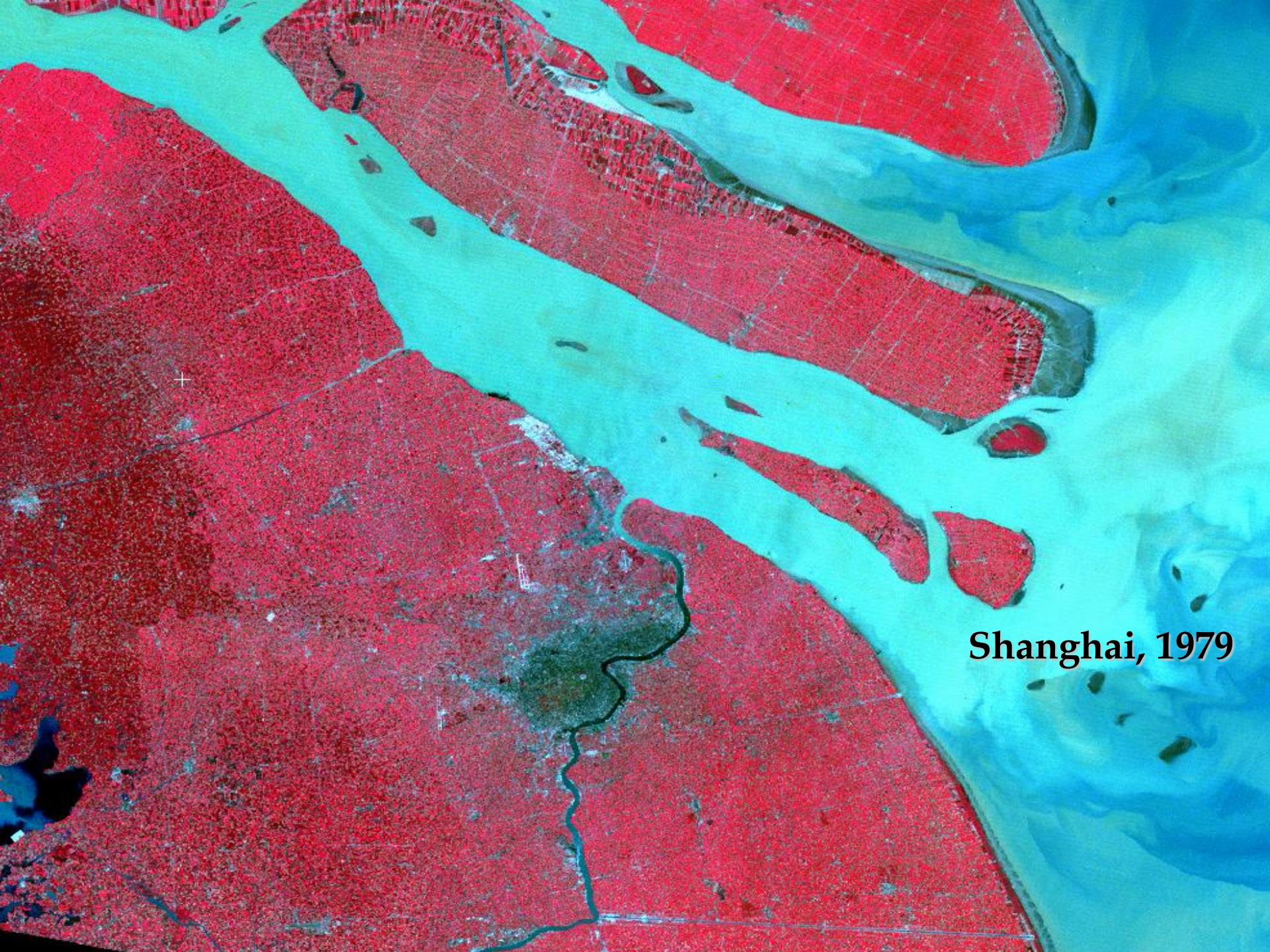
http://due.esrin.esa.int/page_news321.php

Global Urbanization Trend

- In 2008, more than 50% of the world live in cities.
- By 2050, the world is expected to add an additional 2.5 billion urban dwellers;
- with nearly 90 percent of the increase concentrated in Asia and Africa. (United Nations, 2014).




Dubai
1973


Shanghai, 1979


Shanghai, 2001


Shanghai, 2010

Environmental Consequences

High concentrations of aerosols, exhaust gases, pollution and dust

- Hazardous to health
- Increased smog, haze, fog, clouds

Source: The Associated Press

Source: Suicup via Wikimedia

Environmental Consequences

- **Paved surfaces -> rainfall water -> flooding**
  - Urbanization results in more impervious surfaces, thus reducing the area where infiltration to ground water can occur. Thus, more storm water runoff occurs.
  - 79 people died in July 2012 Beijing flooding

Source: rendezvous.blogs.nytimes.com

Source: BBC News

Source: www.theatlanticcities.com

Environmental Consequences

Urban heat island (UHI) and heat waves

- UHI – urban air temperatures higher than surrounding rural areas.
- The average air temperature in a city with 1 million inhabitants is 1-3 degrees warmer.
- Heat waves: In the afternoon, the difference can be 12 degrees warmer, no night time cooling. Death rate raise during heat waves.

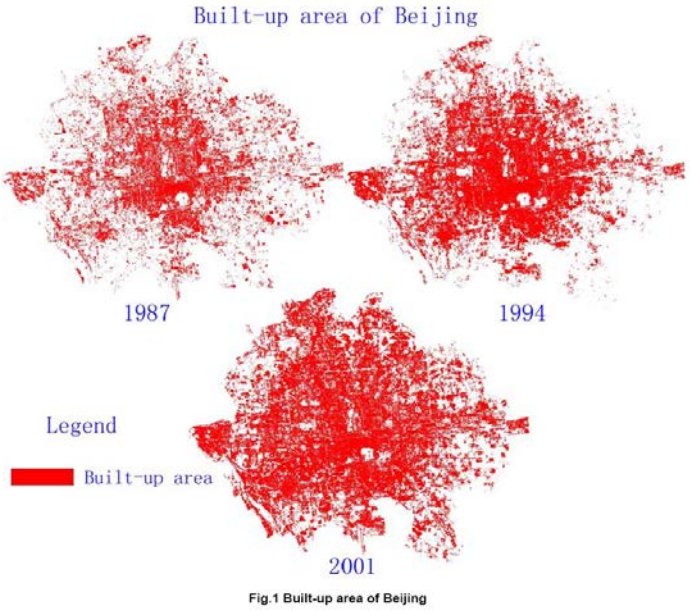
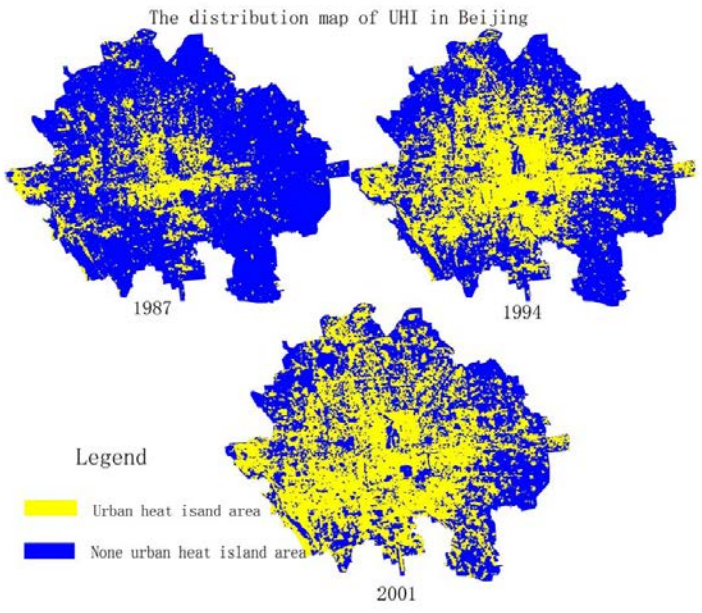


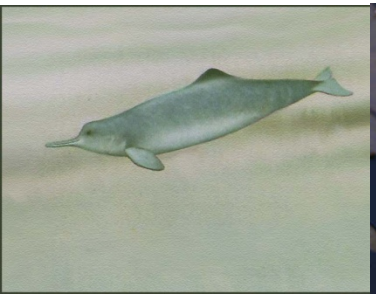
Fig.1 Built-up area of Beijing



Environmental Impact

The growth of urban areas & subsequent transportation networks generates a host of environmental impacts

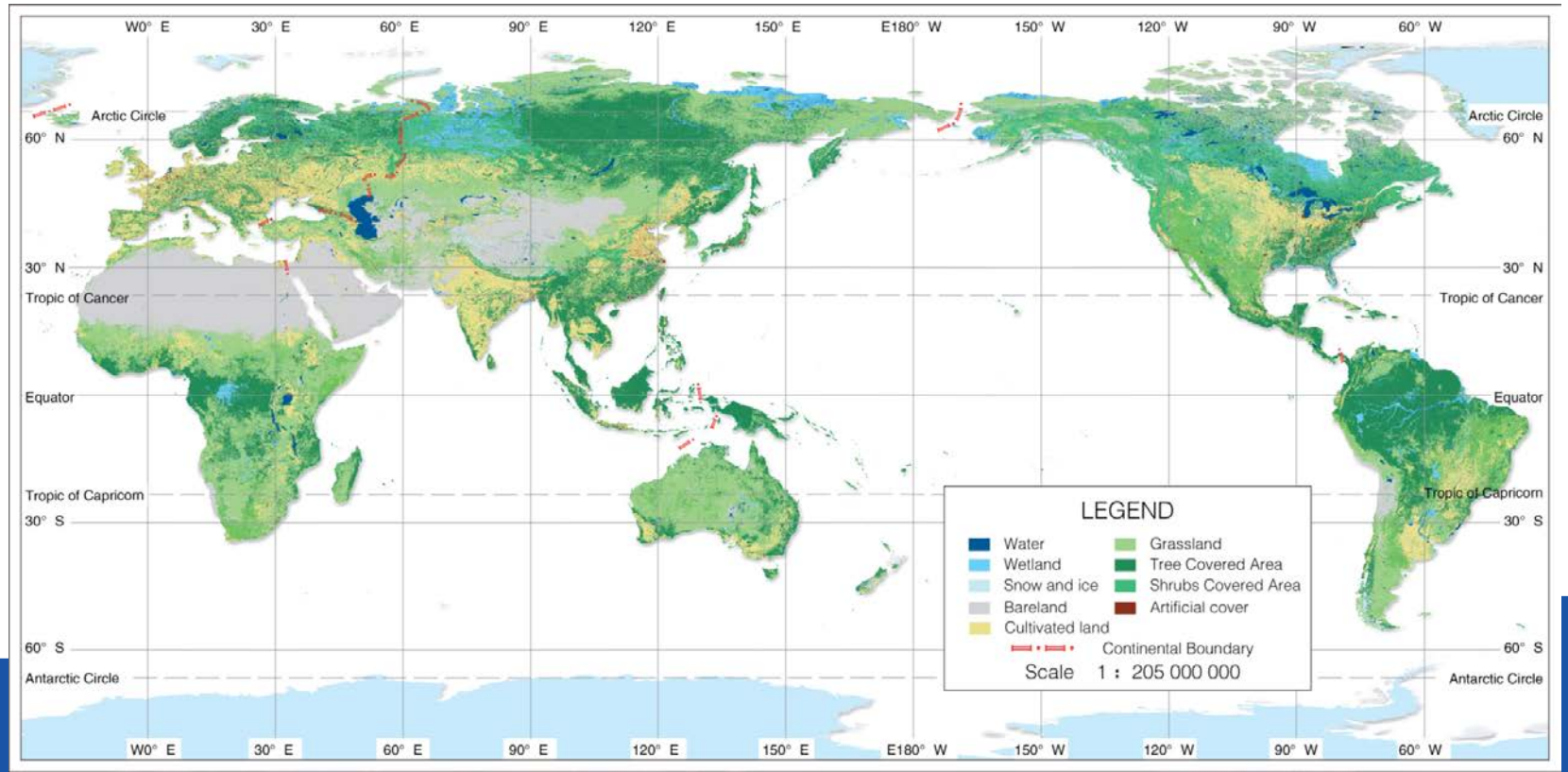
- Deforestation, habitat fragmentation and loss of biodiversity
- Loss of high quality farmland
- Contamination of Lakes and other waterways
- Increases in fossil fuel consumption & emissions of greenhouse gases





Existing Global Urban Data in GLC Products

- Derived from optical data (TM, MERIS, MODIS, etc.)
- Data gaps: difficulties to acquire images in appropriate seasons
- Information gaps:
  - Confusions among various classes such as bare soil and built-up areas
  - One class on urban extent, no detailed urban land cover info



Existing Global Urban Data in GLC Products

1. Comparison of GLC maps with regional LC datasets: Urban

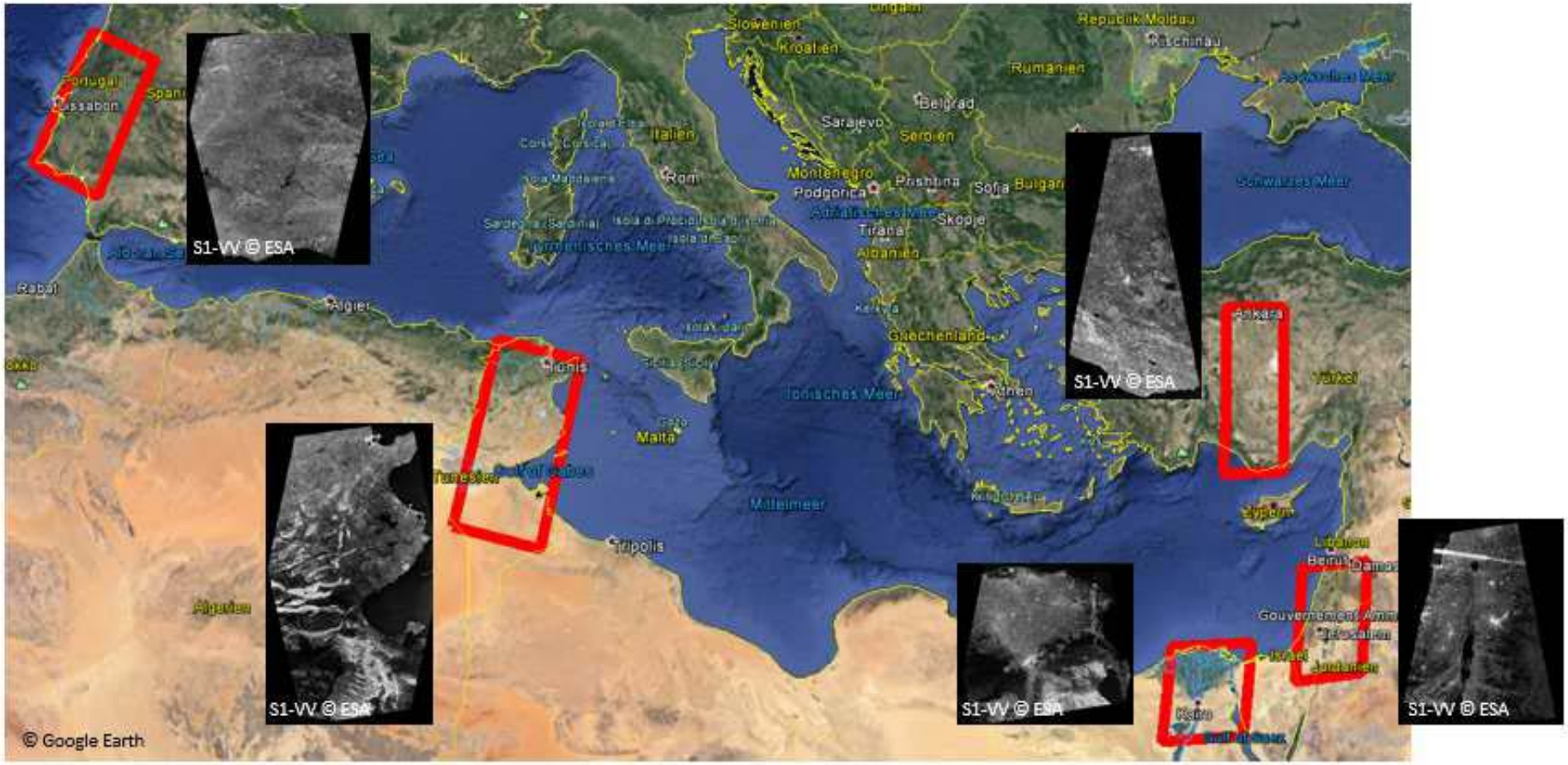
Regional LC datasets	Urban classification	LC-CCI 2005	MODIS 2005	GlobCover 2005
Europe CORINE-LC 06	Correspondence %	51.4	35.5	28.0
	Fully omitted %	19.6	40.3	39.6
USA NLCD-LC 06	Correspondence %	52.4	55.1	19.4
	Fully omitted %	16.1	14.1	22.1
Indonesia IND-MOFOR LU-06	Correspondence %	7.8	22.1	8.4
	Fully omitted %	54.0	42.1	69.4
Brazilian Amazon Terra Class 2008	Correspondence %	37.2	36.1	8.1
	Fully omitted %	31.8	30.0	67.2
Average correspondence %		37.2	37.2	15.9

% of total urban area in reference

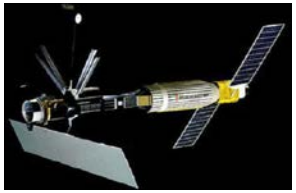
- The LC-CCI performed better in Europe, USA and Brazilian Amazon, in terms of classifying urban areas. Urban areas in Indonesia were poorly detected.
- In detecting urban areas, the LC-CCI urban detection was worse in Indonesia than other regions.
- General trend of underestimating urban areas.
- On average, the LC-CCI and MODIS have better correspondence, however it needs improvement.

WAGENINGEN UNIVERSITY
WAGENINGEN UR

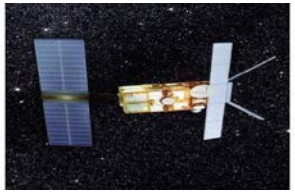
Land Cover CCI: Urban Round Robin



Spaceborne SAR Systems



SEASAT
NASA/JPL (USA)
L-Band, 1978

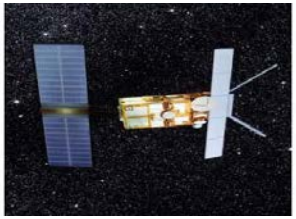


ERS-1
European Space Agency (ESA)
C-Band, 1991-2000

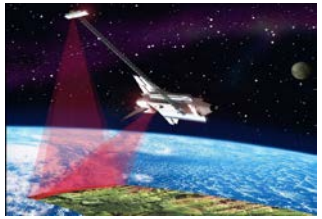
J-ERS-1
Japanese Space Agency (NASDA)
L-Band, 1992-1998

SIR-C/X-SAR
NASA/JPL, L- and C-Band (quad)
DLR / ASI, X-band
April and October 1994

RadarSAT-1
Canadian Space Agency (CSA)
C-Band, 1995-today



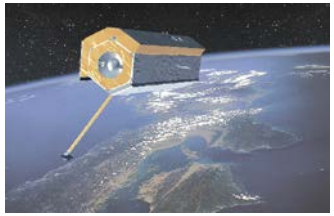
ERS-2
European Space Agency (ESA)
C-Band, 1995-today



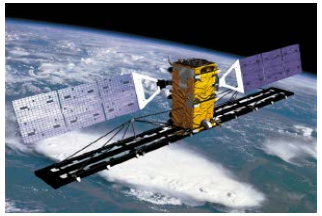
Shuttle Radar Topography Mission (SRTM)
NASA/JPL (C-Band), DLR (X-Band)
February 2000

ENVISAT / ASAR
European Space Agency (ESA)
C-Band (dual), 2002-today

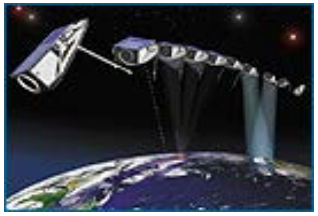
ALOS / PALSAR
Japanese Space Agency (NASDA)
L-Band (quad), 2004



TerraSAR-X
German Aerospace Center (DLR) / Astirum
X-Band (quad), 2005



RadarSAT-II
Canadian Space Agency (CSA)
C-Band (quad), 2005



SAR-Lupe
BWB, Germany
X-Band, 2005

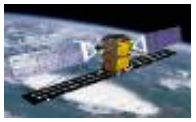
Range / Azimuth Resolution

30m 10m 3m 1m 10cm

ENVISAT / ASAR

SENTINEL-1

RADARSAT 1



RADARSAT 2

Cosmo-Skymed

TerraSAR-X

ERS 1&2

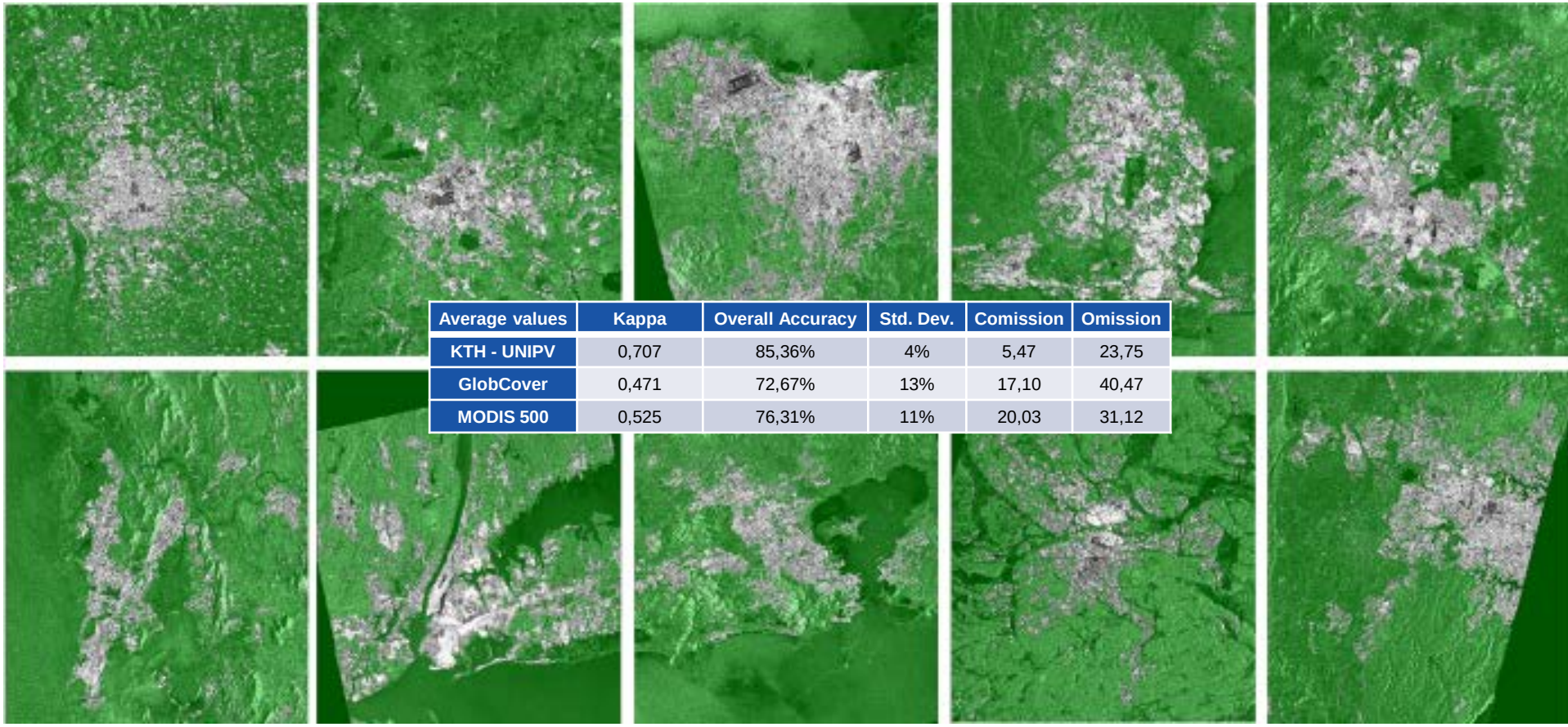
ALOS

SENTINEL-1

TerraSAR-X

Urban Extraction: ENVISAT ASAR Data

Beijing Berlin Jakarta Lagos Mexico City



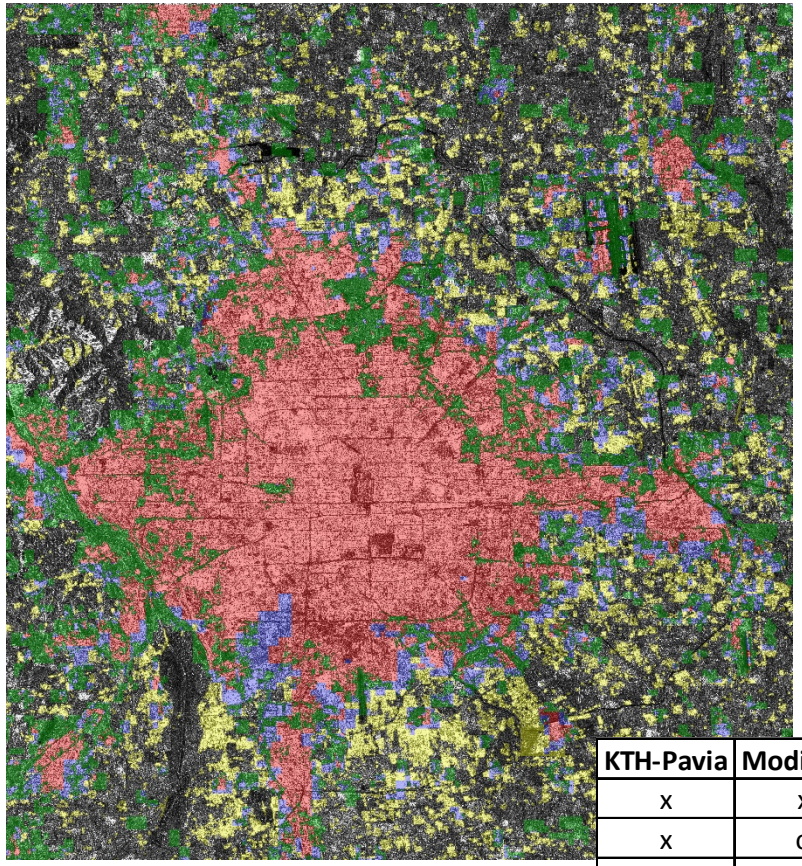
Average values	Kappa	Overall Accuracy	Std. Dev.	Comission	Omission
KTH - UNIPV	0,707	85,36%	4%	5,47	23,75
GlobCover	0,471	72,67%	13%	17,10	40,47
MODIS 500	0,525	76,31%	11%	20,03	31,12

Mumbai New York City Rio de Janeiro Stockholm Sydney

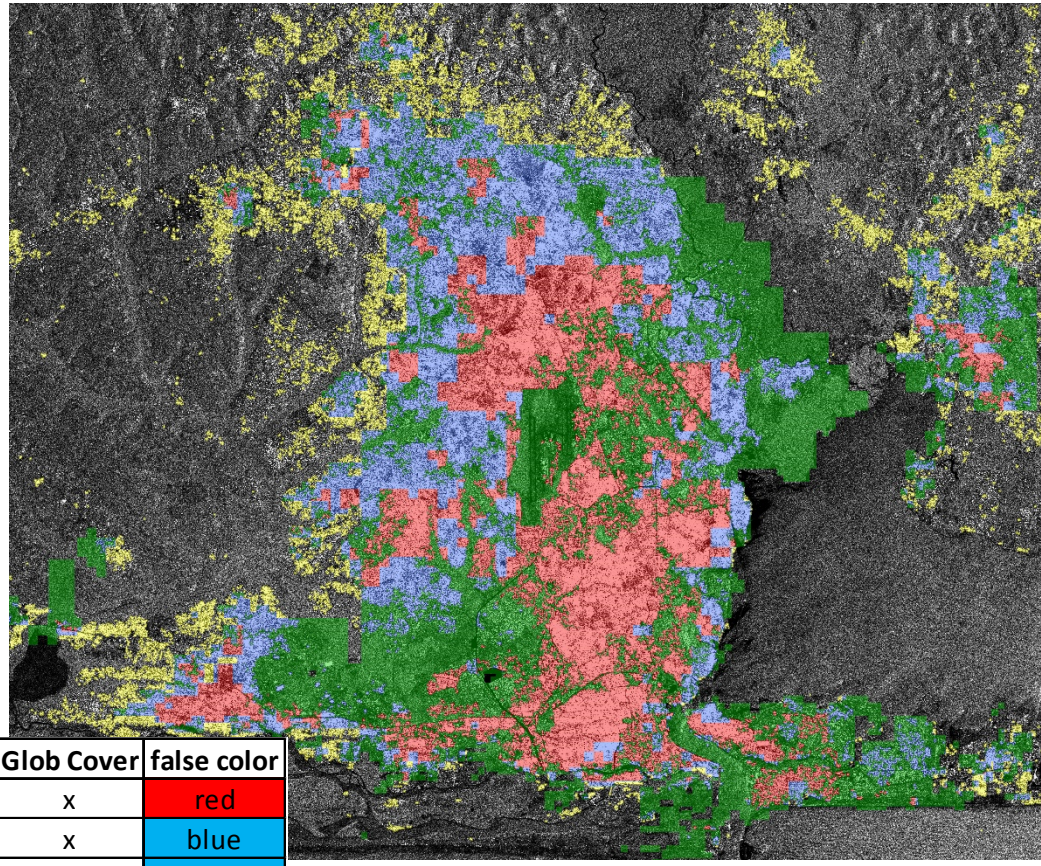
Ban, Y. and A. Jacob & P. Gamba, 2015. Spaceborne SAR Data for Global Urban Mapping at 30m Resolution Using a Robust Urban Extractor. *ISPRS J. of Photogrammetry & Remote Sensing*

KTH-Pavia vs. MODIS 500 & GlobCover

Beijing 2009



Lagos 2010



KTH-Pavia	Modis 500	Glob Cover	false color
x	x	x	red
x	o	x	blue
x	x	o	blue
x	o	o	yellow
o	x	x	green
o	o	x	green
o	x	o	green

Sentinel-1A SAR & -2A MSI Data

EO4Urban: Objectives

- The overall objective is to evaluate multi-temporal multi-resolution Sentinel-1A SAR and Sentinel-2A MSI data for developing a pilot global urban services based on user requirements to support smart and sustainable urban development.

The Stockholm County Administrative Board's Challenges

Very high demand for housing and regional development

VS

National interests for

sustainable development

climate impact

Infrastructure

Green structure and biodiversity

Stockholm County User Needs

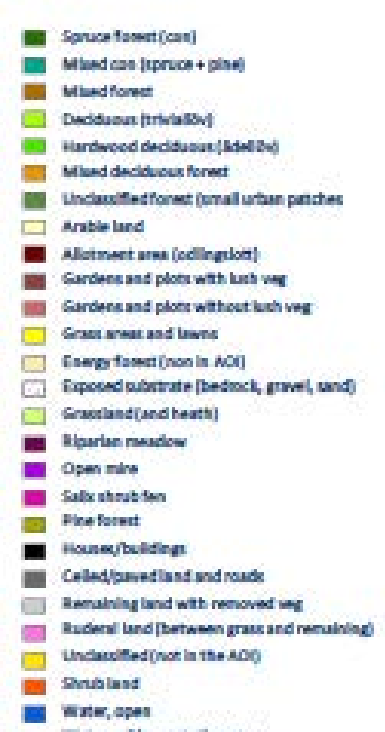
Up-to-date, accurate information on urban land cover and development in the region (Urban land cover & change map).

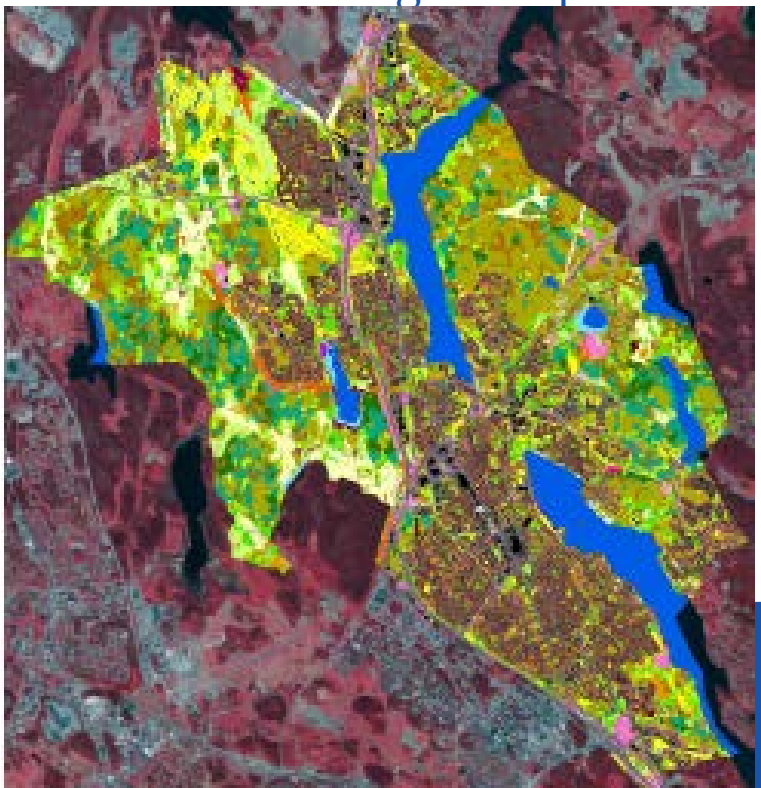
- Currently using CORINE land cover map from 2000 for planning activities
- No viable way to see what areas are being developed after approved planning.
- Construction process is often several years.
- Up to two years delay for finished construction to be registered in the national database.

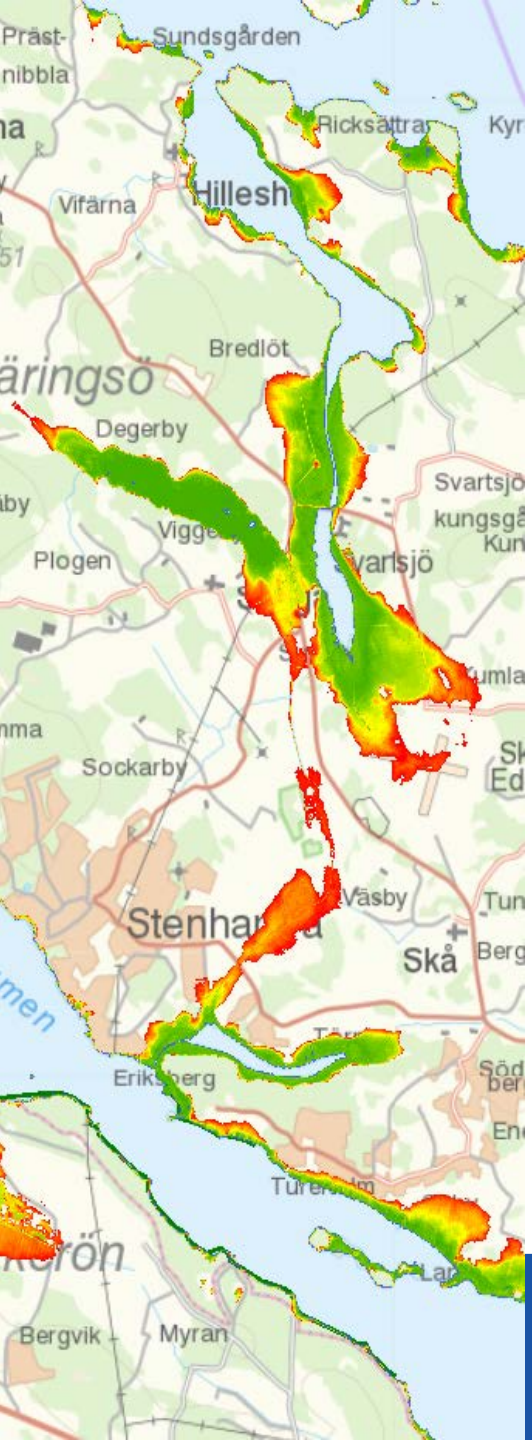
Stockholm County User Needs

Spatial & Temporal Information on Urban Green Structure

- SCAB is charged with overseeing green structure and maintaining the biodiversity of the Stockholm region
- Mapping green structure and monitoring changes
- No accurate biotope database exists for the region
- Lots of field work, lots of manual image interpretation





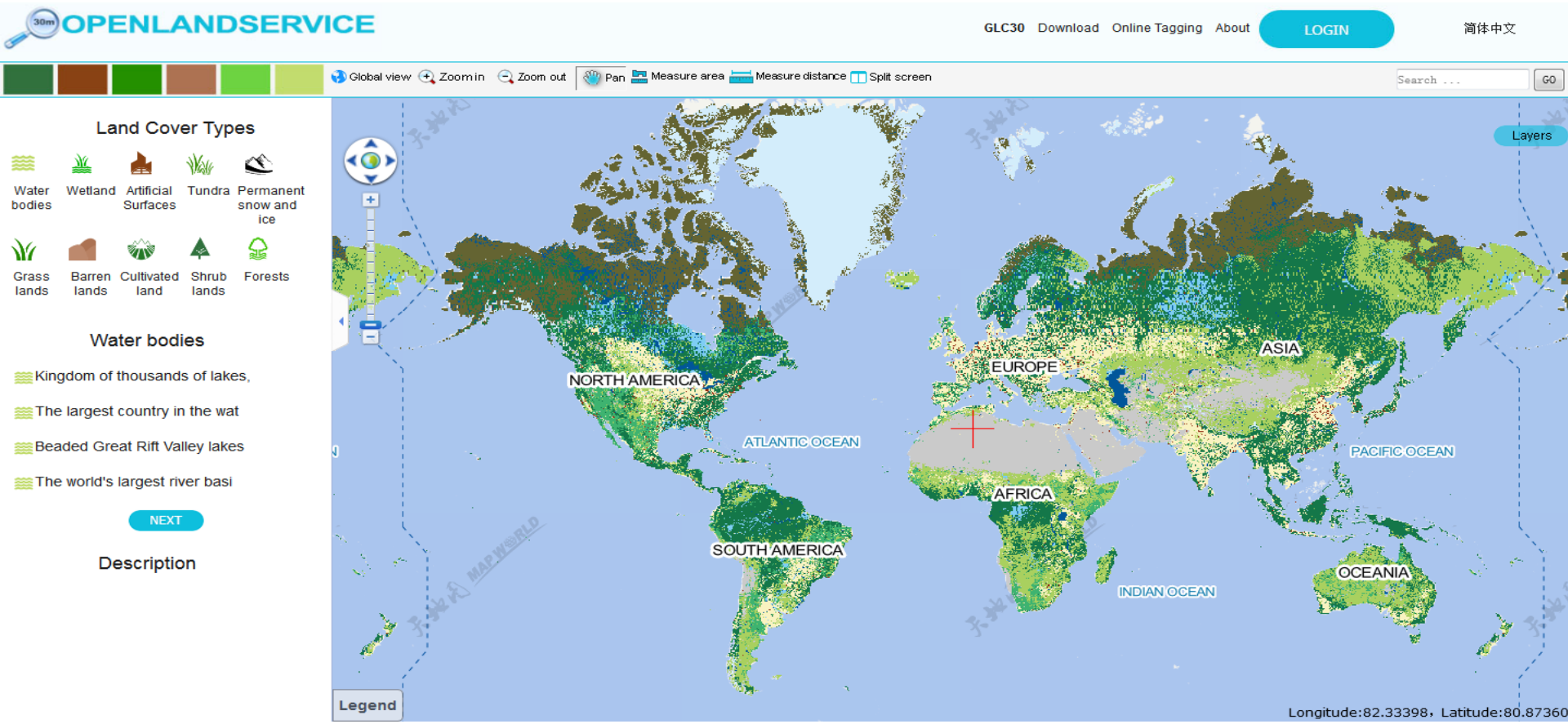


Stockholm County User Needs

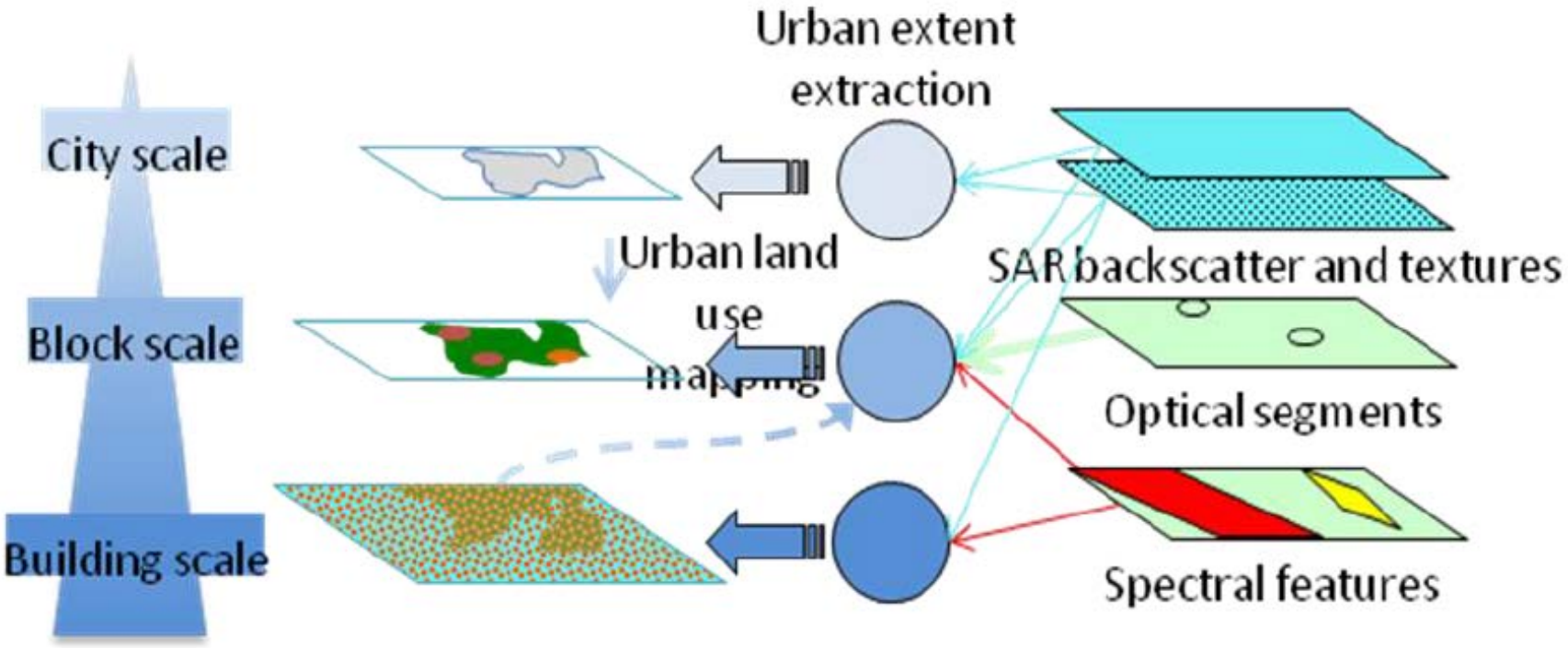
Supporting Flooding Risk Analysis

- Climate change is a very important factor in sustainable planning.
- We lack good information on impervious surface classes for flooding analysis.
- The coastline today is derived from Swedish National Land Survey data and provides static maps. We wish to follow the developments.

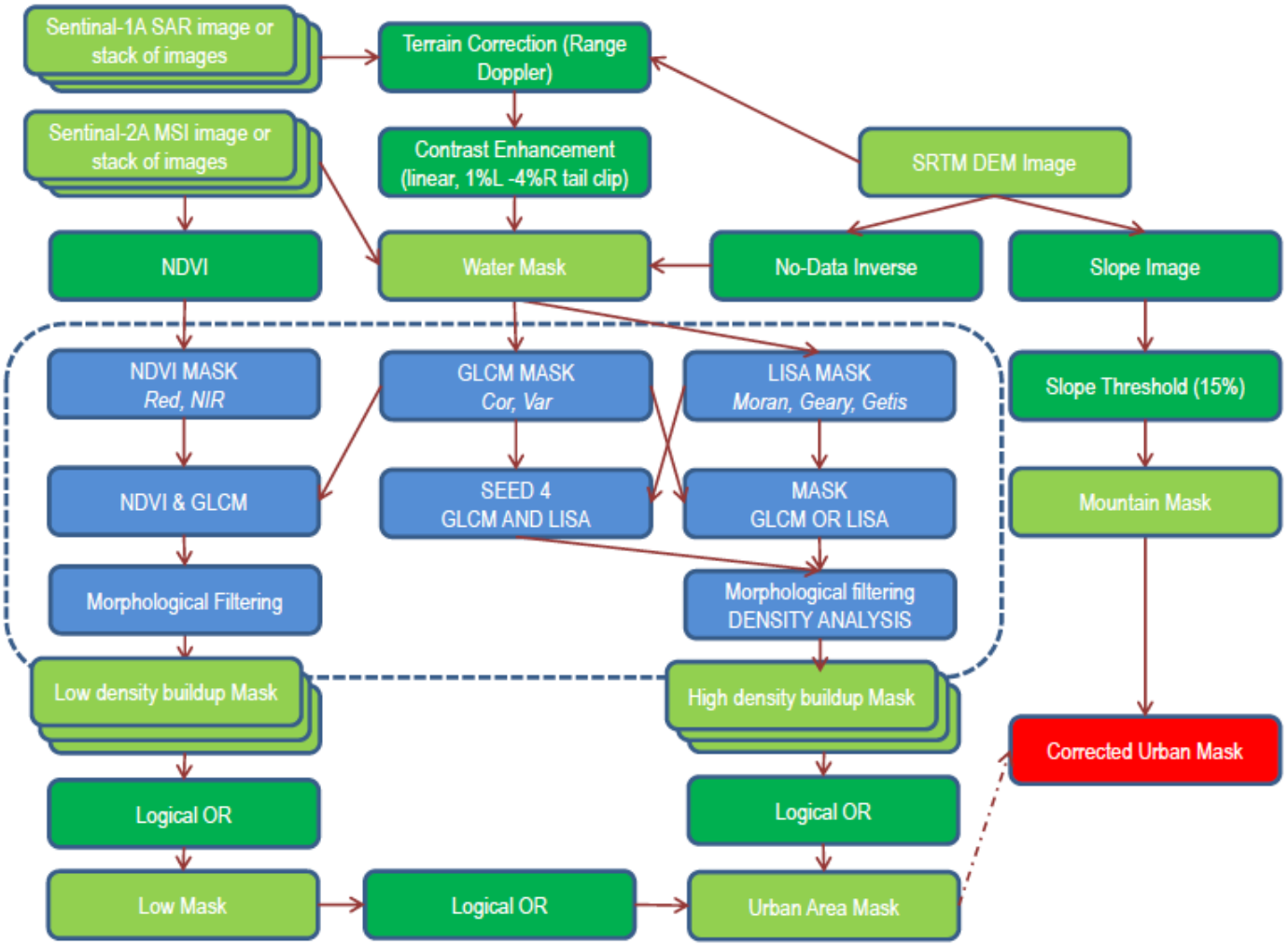
National Geomatics Center of China
User Needs



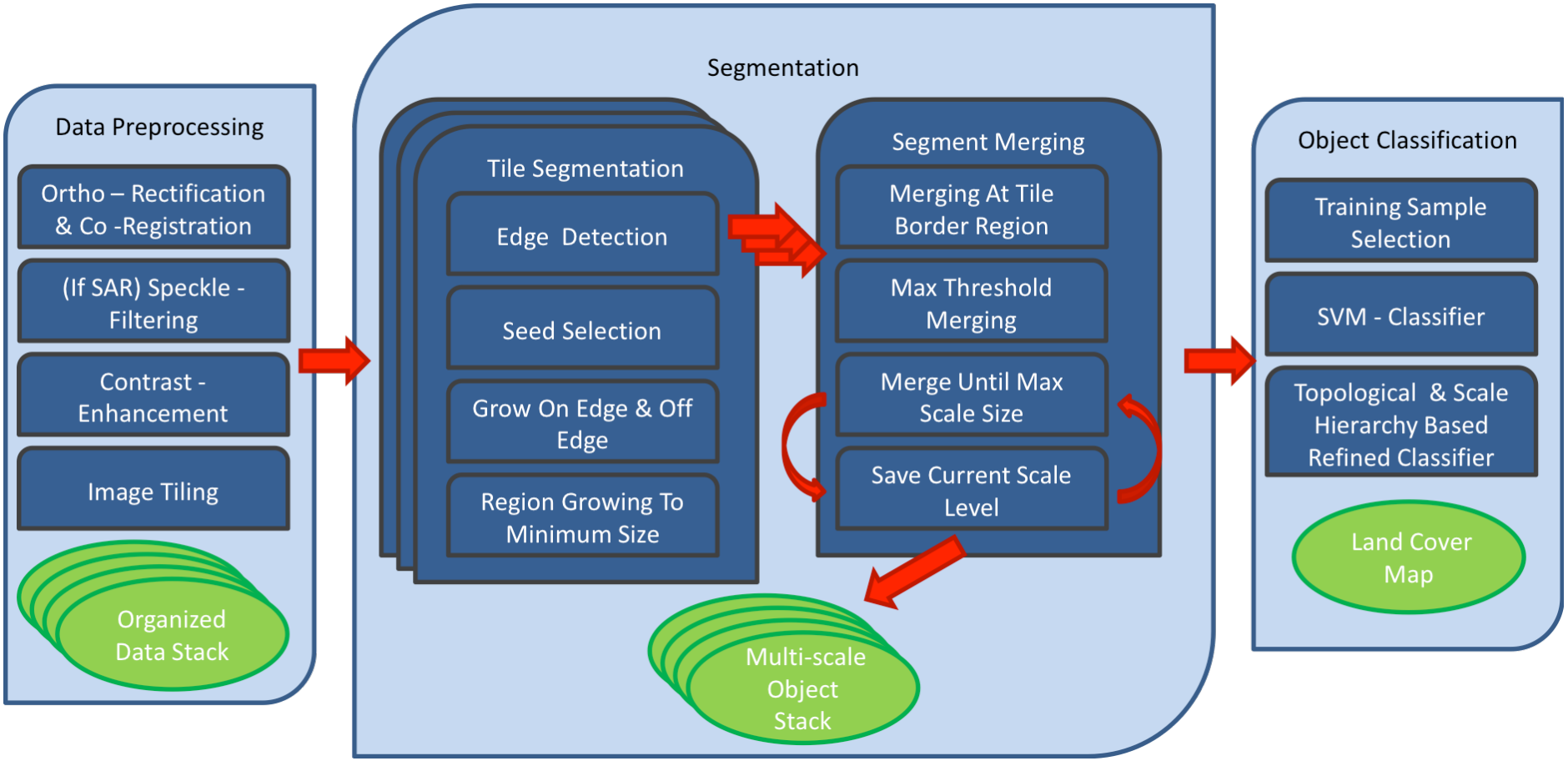
Methodology



Methodology

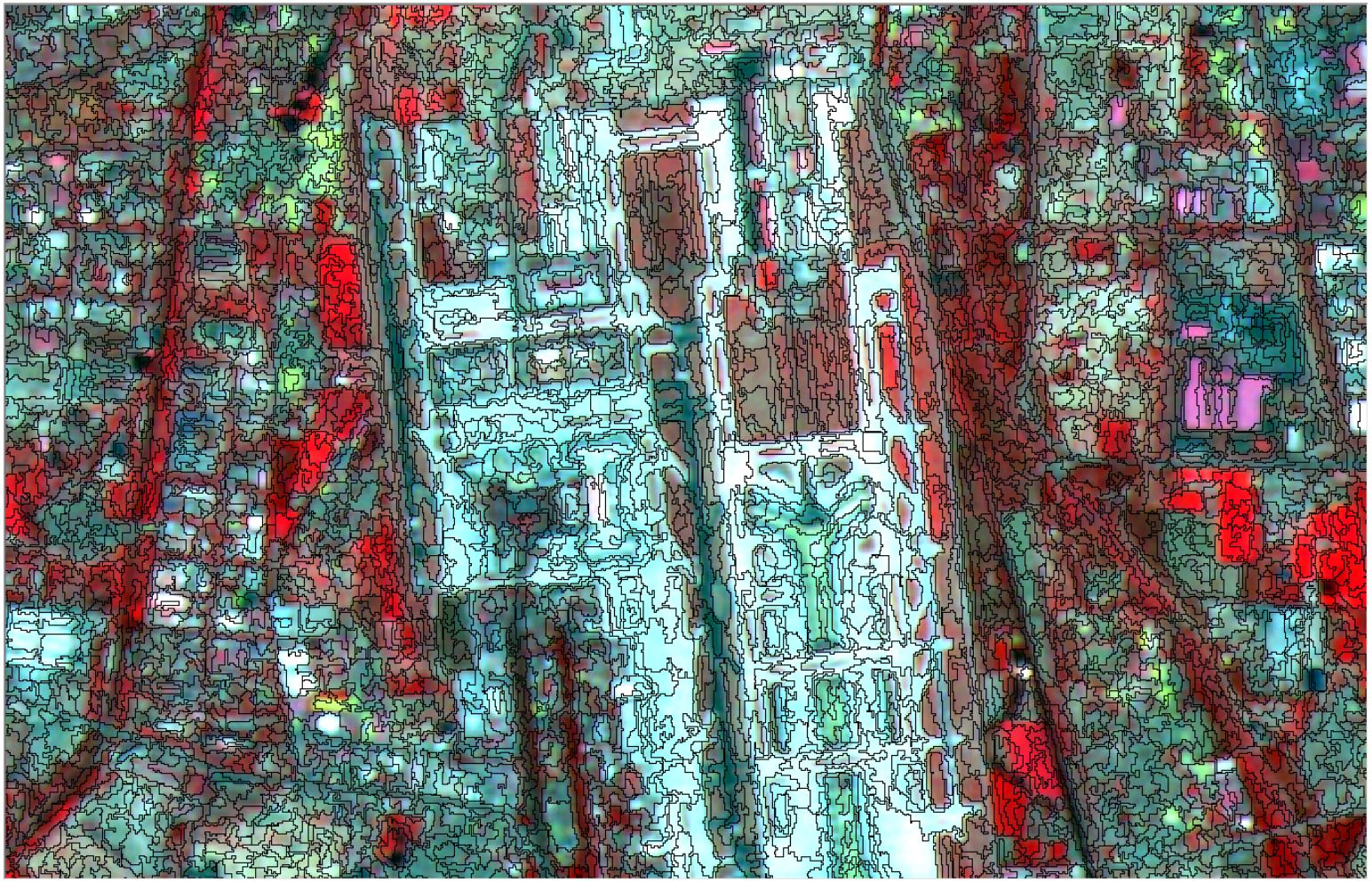


Methodology



Ban, Y. and A. Jacob, 2013. Object-based Fusion of Multitemporal Multi-angle ENVISAT ASAR and HJ-1 Multispectral Data for Urban Land-Cover Mapping. *IEEE Transaction on GeoScience and Remote Sensing*, Vol. 51, No. 4, pp. 1998-2006.

KTH-SEG: Stepwise Example

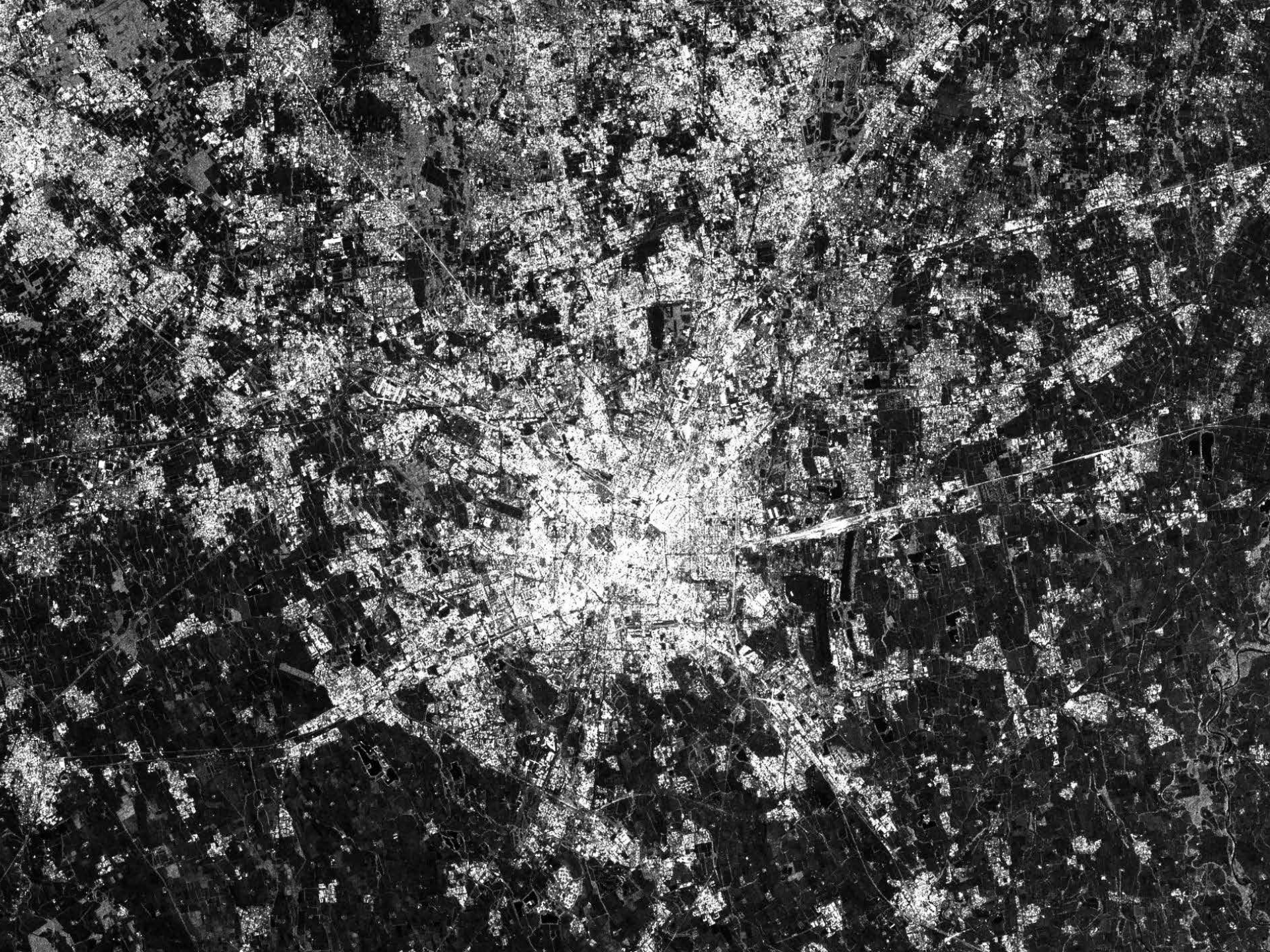


Deng, J and Y. Ban *et al.*, 2014. Hierarchical Segmentation of Multitemporal RADARSAT-2 SAR Data Using Stationary Wavelet Transform and Algebraic Multigrid Method. *IEEE Transaction on GeoScience and Remote Sensing*. VOL. 52, NO. 7, pp. 4353-4363.

Study Areas

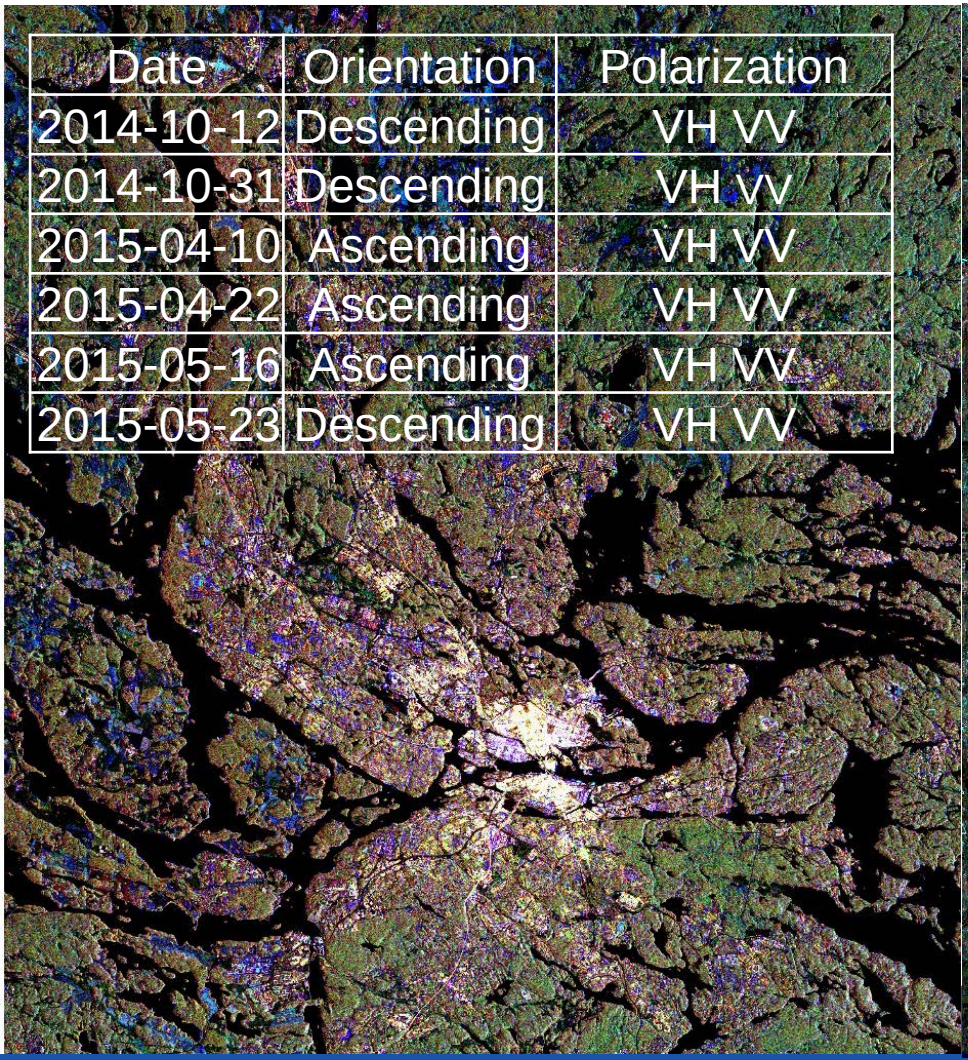

Stockholm
EUROPE
NORTH
AMERICA
ASIA
Milan / Lombardy
New York City
North
Atlantic
Beijing
Mexico City
Mumbai
AFRICA
Lagos
SOUTH
AMERICA
Jakarta
Indian
Ocean
Rio De Janeiro
AUSTRALIA
South
Pacific
South
Atlantic
Sydney


Sentinel-1A SAR: Nanchang



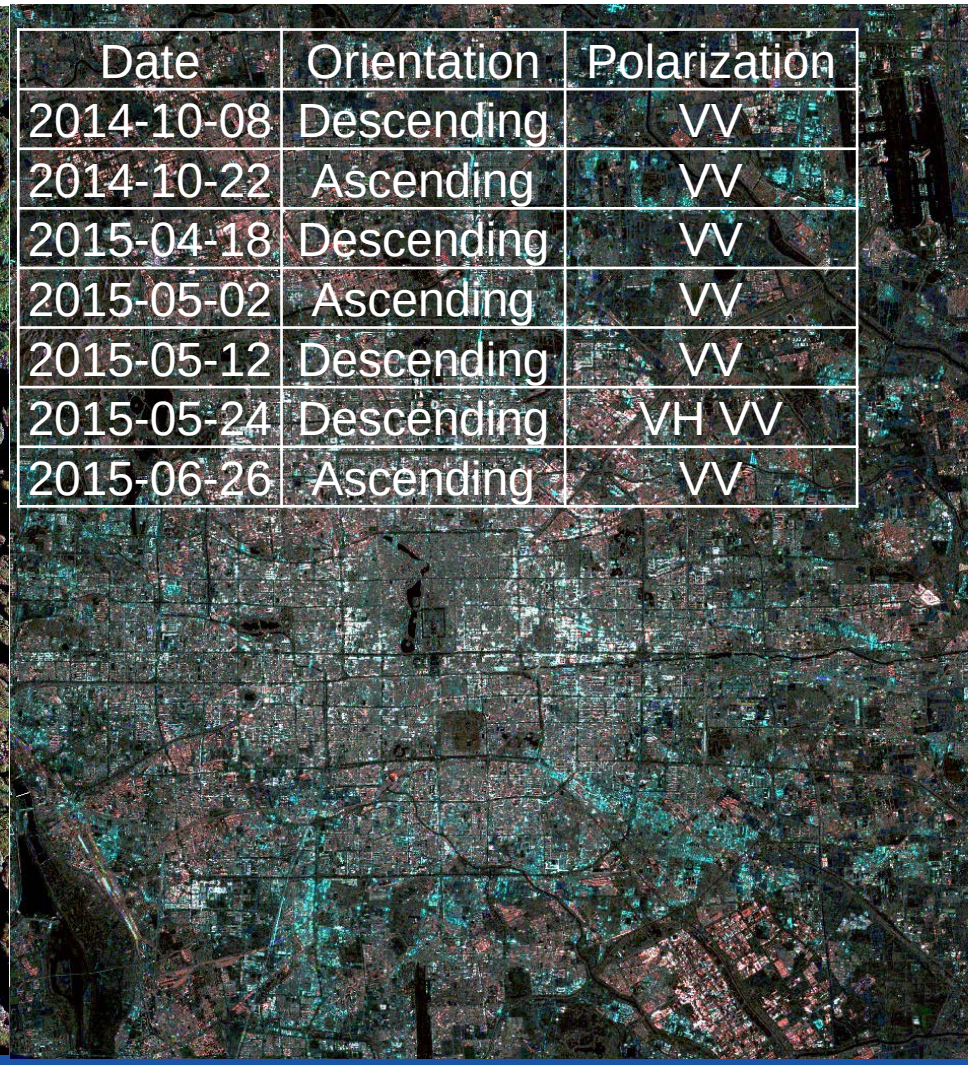
Multitemporal Sentinel-1A SAR Data

Date	Orientation	Polarization
2014-10-12	Descending	VH VV
2014-10-31	Descending	VH VV
2015-04-10	Ascending	VH VV
2015-04-22	Ascending	VH VV
2015-05-16	Ascending	VH VV
2015-05-23	Descending	VH VV



Stockholm

Date	Orientation	Polarization
2014-10-08	Descending	VV
2014-10-22	Ascending	VV
2015-04-18	Descending	VV
2015-05-02	Ascending	VV
2015-05-12	Descending	VV
2015-05-24	Descending	VH VV
2015-06-26	Ascending	VV



Beijing

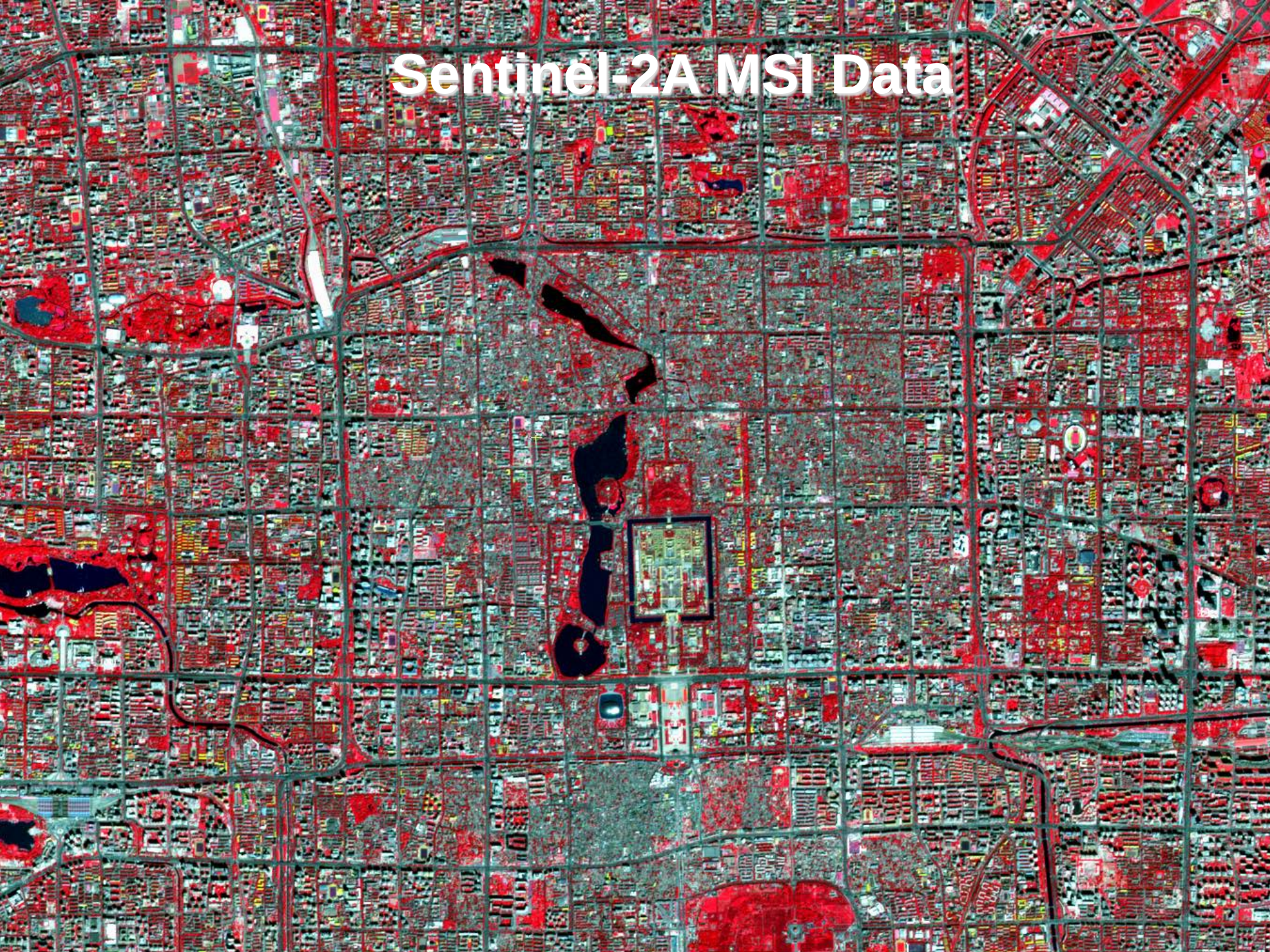
Multitemporal Sentinel-1A SAR Data

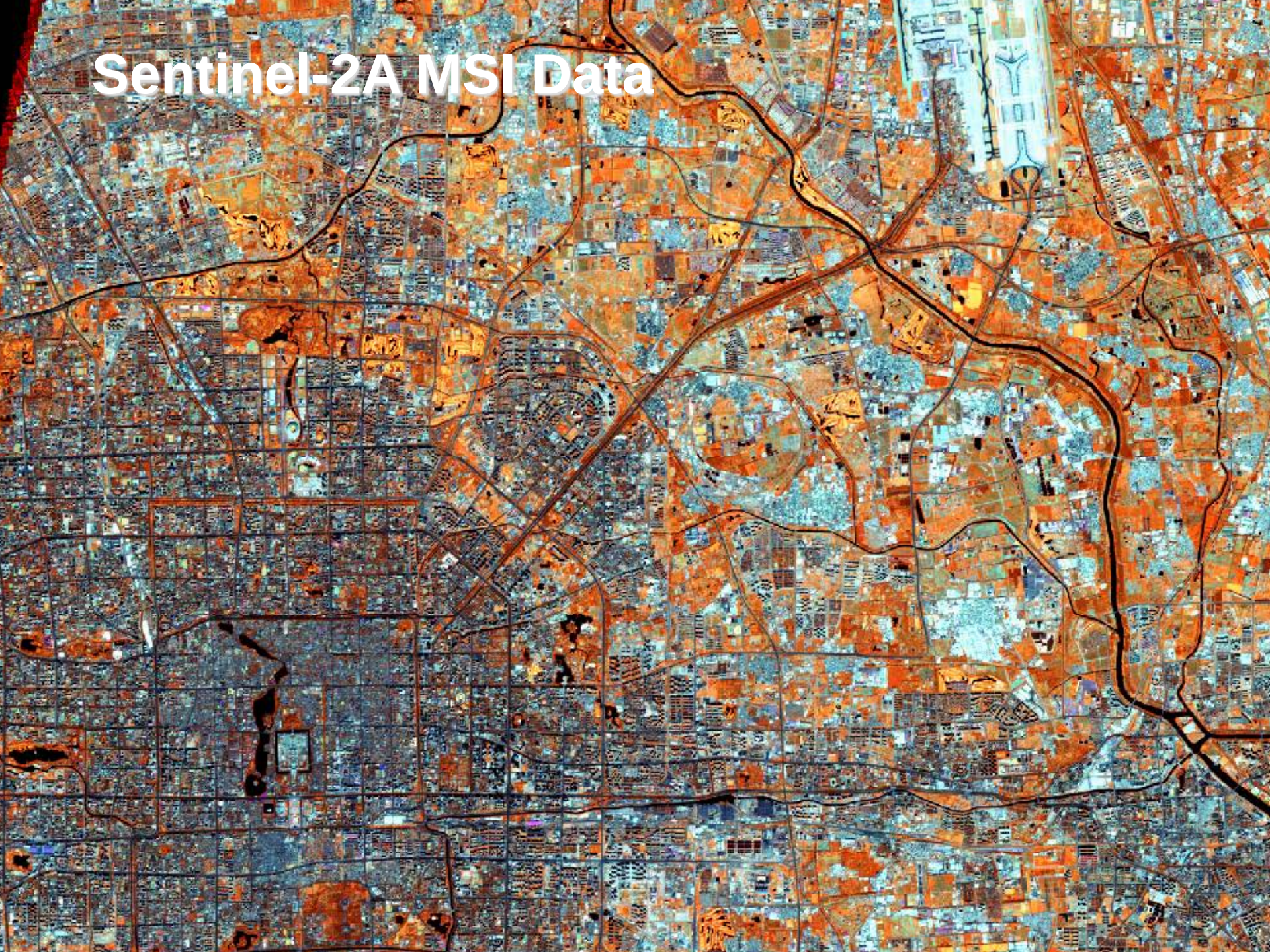
STOCKHOLM

Date	Orbit	Polarization
2015-06-09	Descending	VH VV
2015-06-09	Ascending	VH VV
2015-06-28	Descending	VH VV
2015-07-15	Ascending	VH VV
2015-08-08	Descending	VH VV
2015-08-08	Ascending	VH VV
2015-08-20	Ascending	VH VV
2015-09-08	Descending	VH VV

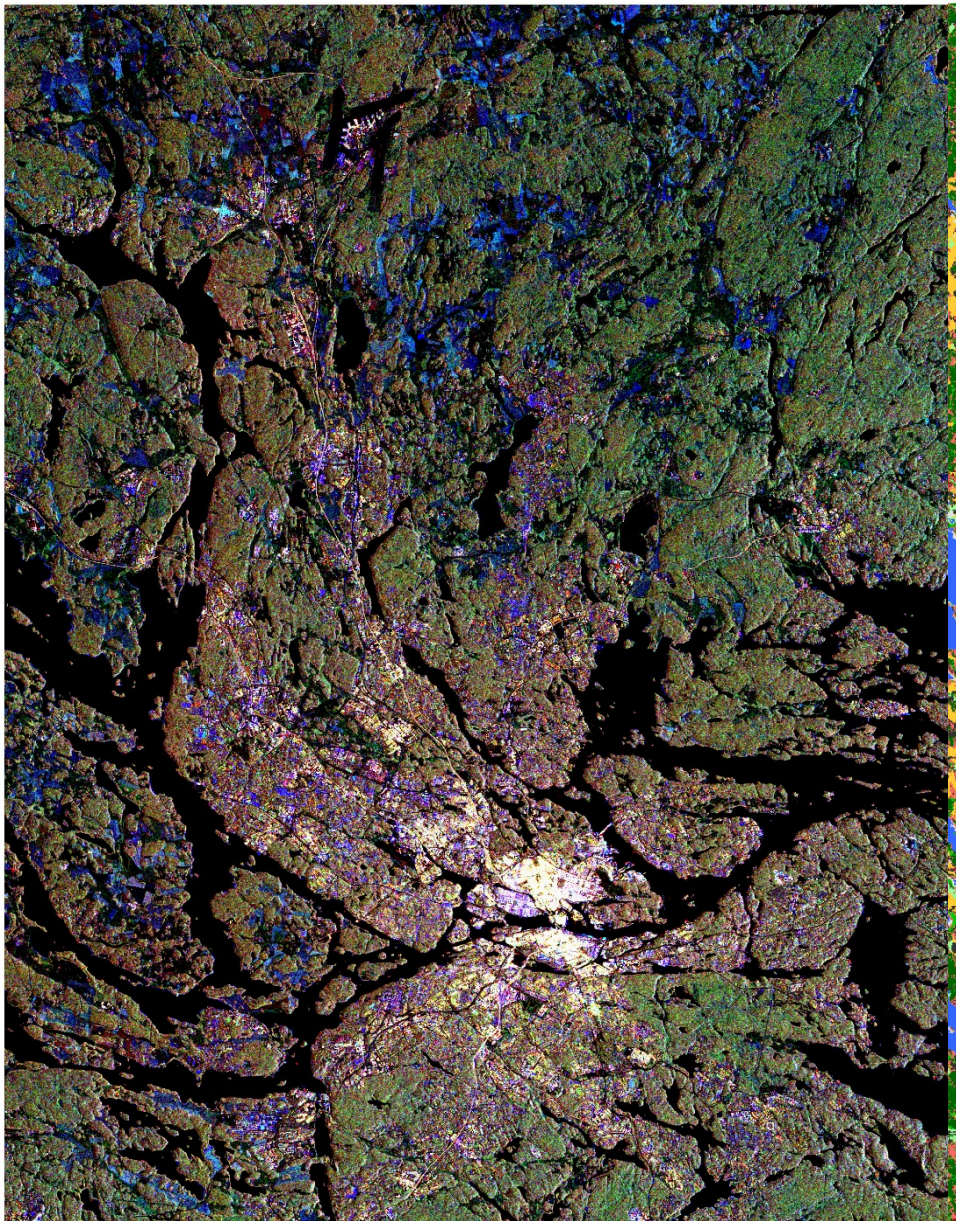
BEIJING

Date	Orbit	Polarization
2015-06-05	Descending	VH VV
2015-06-17	Descending	VH VV
2015-07-23	Descending	VH VV
2015-07-30	Ascending	VH VV
2015-08-23	Ascending	VH VV

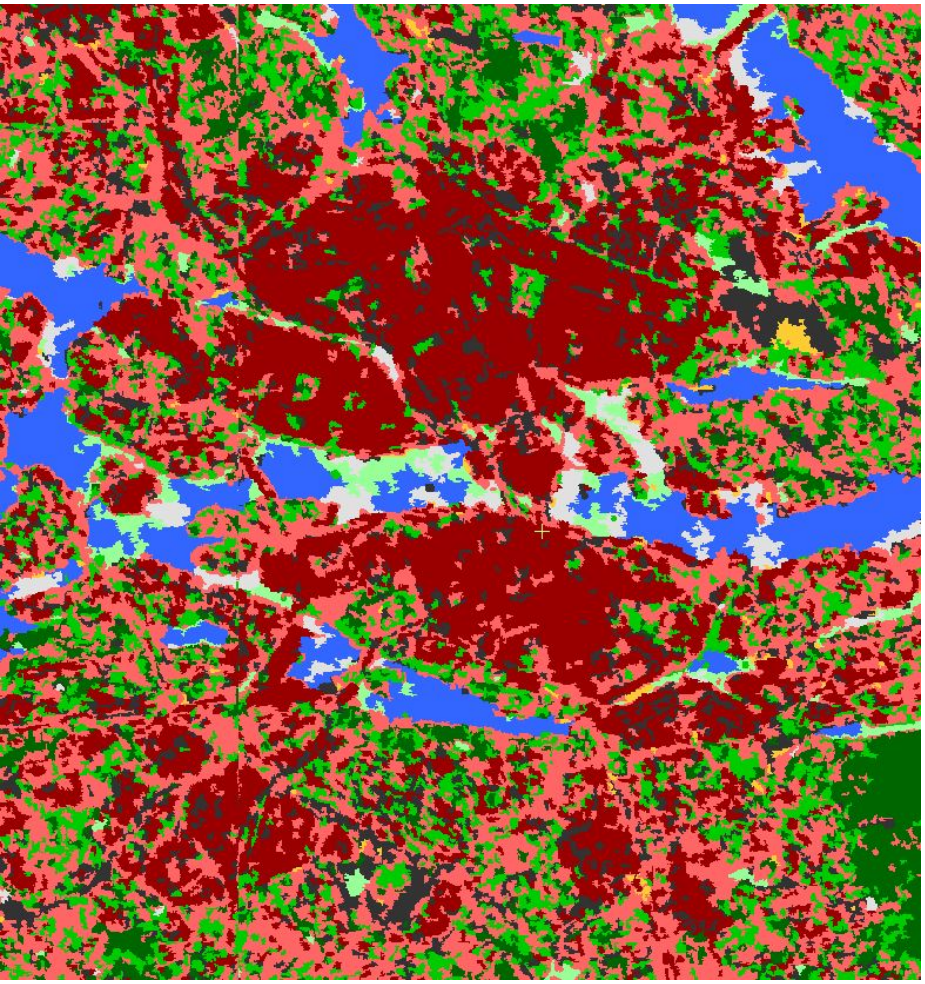

Sentinel-2A MSI Data


Sentinel-2A MSI Data

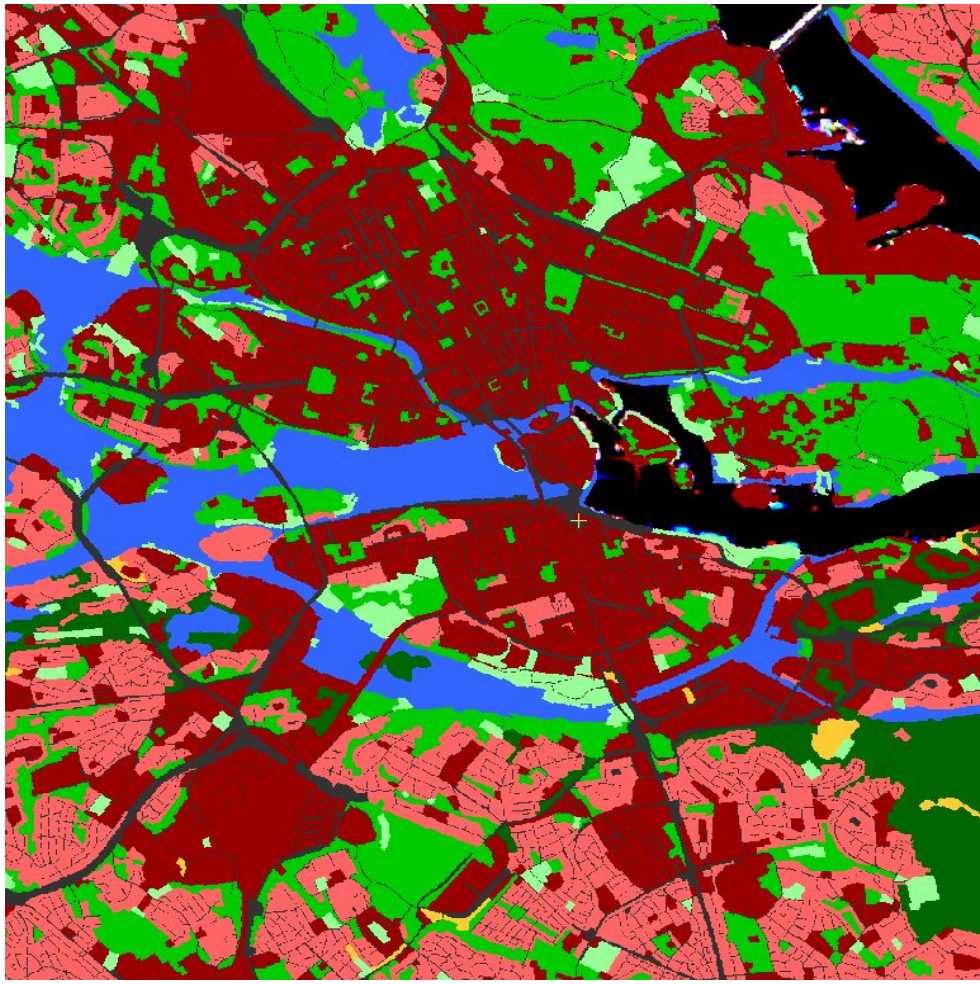
Results: Stockholm



Preliminary Results



KTH-SEG (2015)



Urban Atlas (2010)

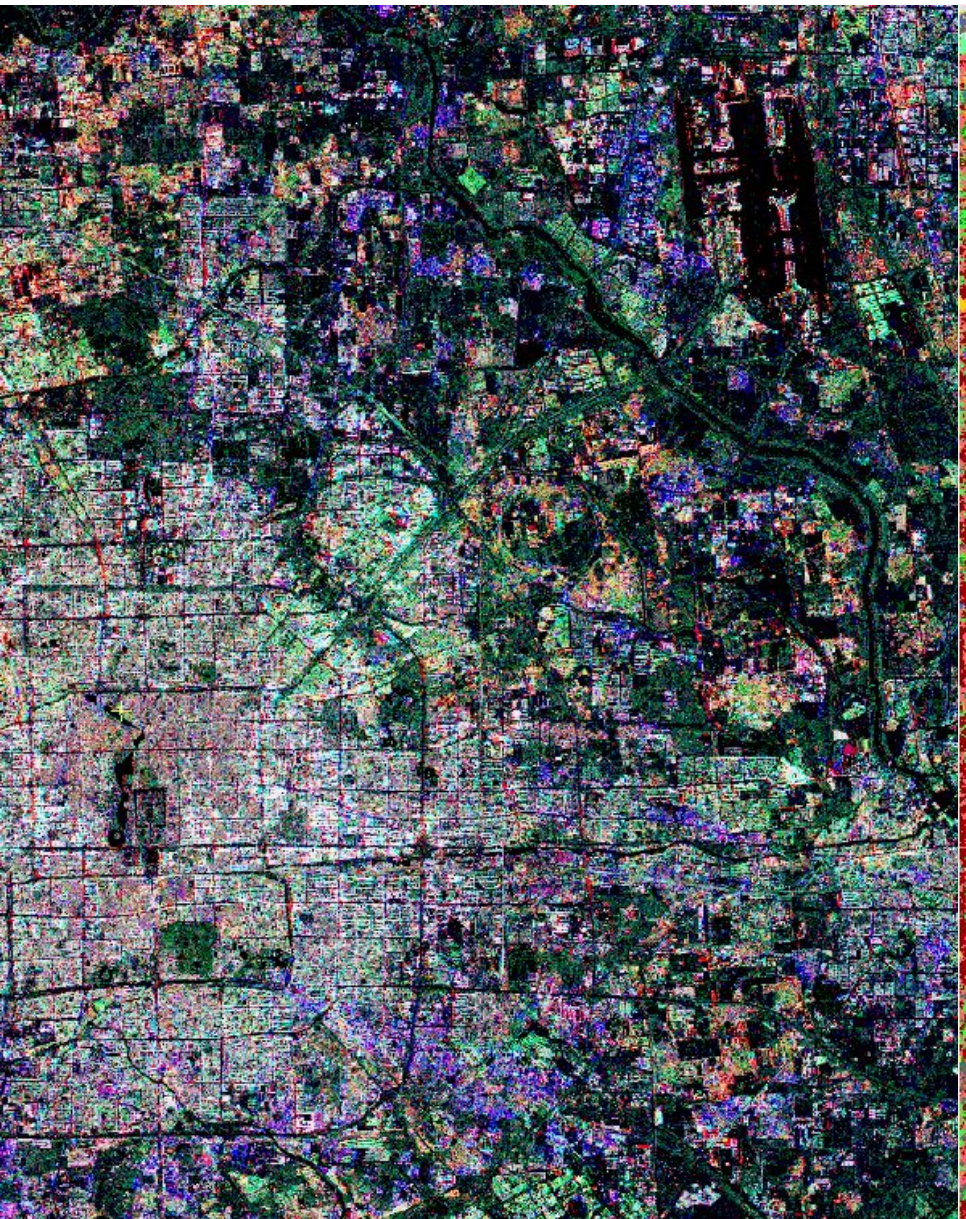
- Water
- Roads
- High Density Builtup
- Low Density Builtup
- Golf Courses
- Forests
- Urban Green Structure
- Agricultural Open Land
- Airport Runways

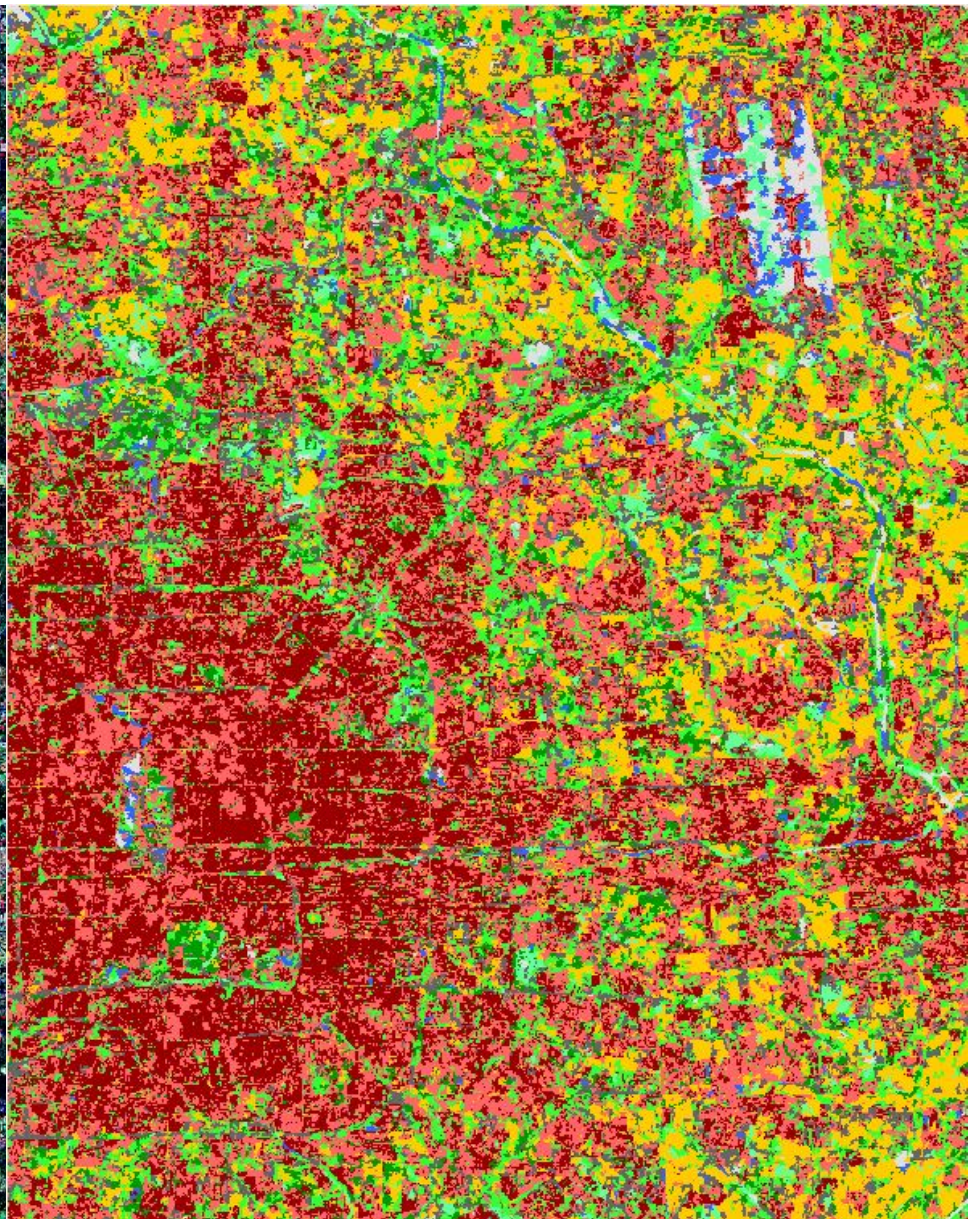
Preliminary Results: Stockholm

Class	Testing	Urban Atlas
Water	97,6	83
Roads	36,5	17,6
High Density Builtup	72,3	31,7
Low Density Builtup	59,4	53,8
Golf course	89,3	29,5
Forest	81	61,9
Urban Green Structure	22,5	20,2
Agricultural Open Land	77,7	37,6
Airport	55,8	36,4
Average Accurracy	**65,8**	**41,3**

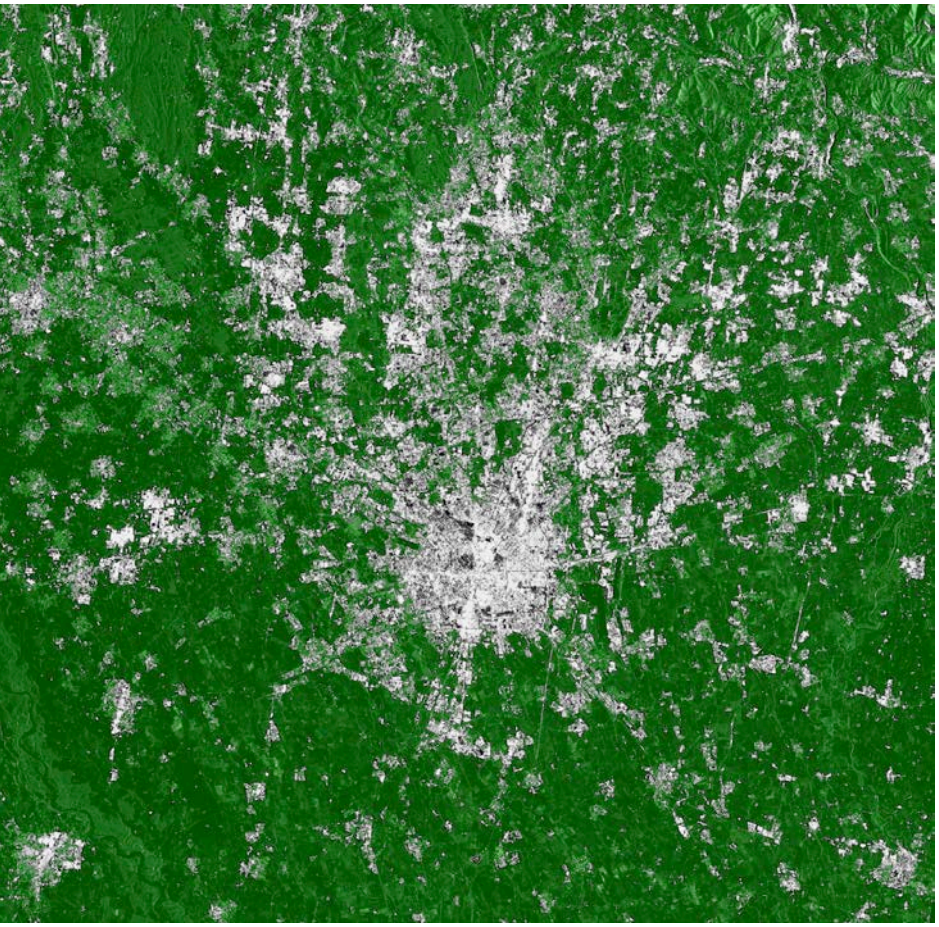
Urban Land Cover Class	High Density Builtup	Low Density Builtup	Roads	Urban Green Structure	Golf Course	Forest	Agricultural /Open Land	Airport Runway	Water
User's Accuracy %	95.1	93	22.6	49.7	54	94.2	70.5	76.3	92
Producer's Accuracy %	100	53	62.2	47.1	59.5	86.3	68.6	91.3	100
Overall Accuracy %	**71.26**				**Kappa**	**0.67**			

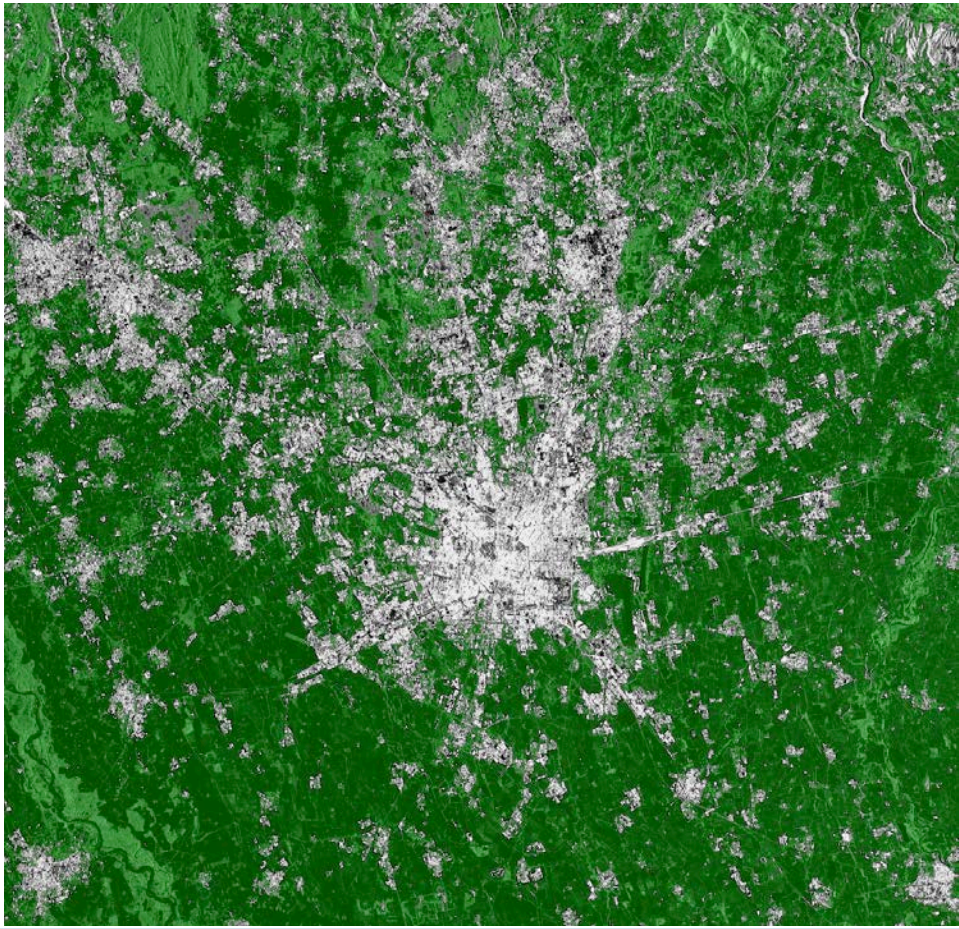
Results: Beijing



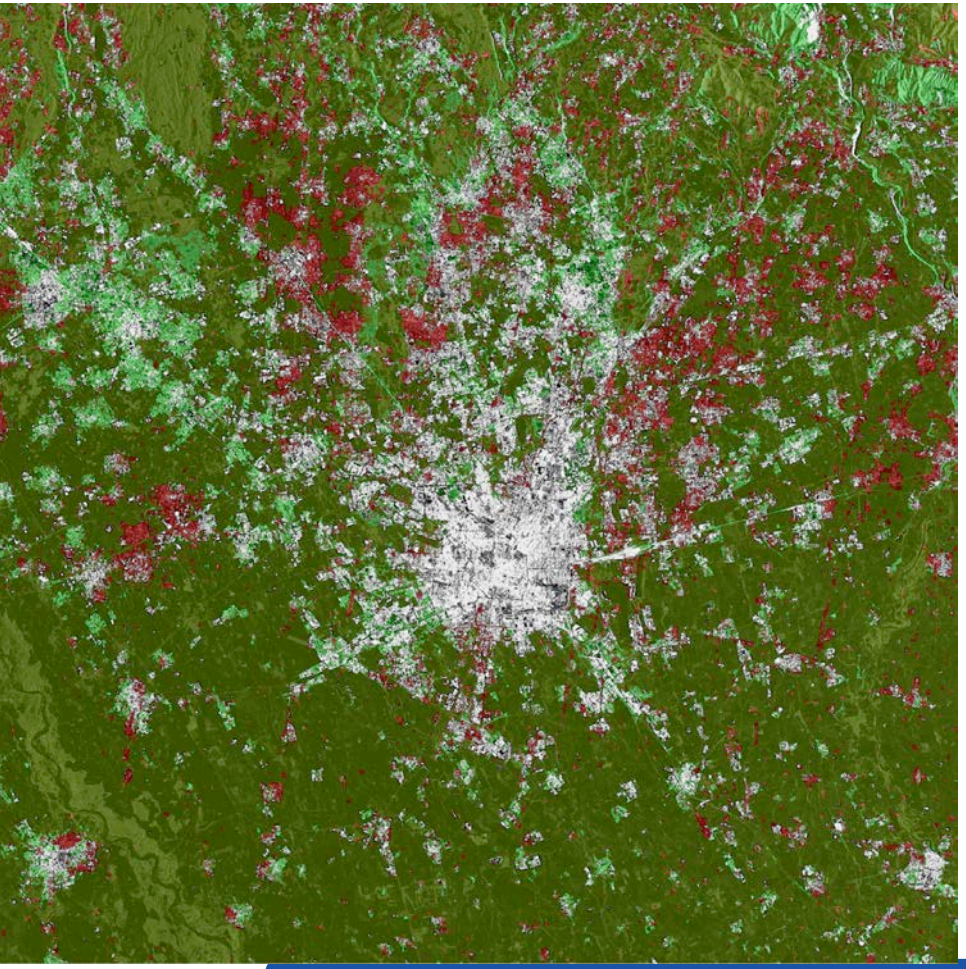


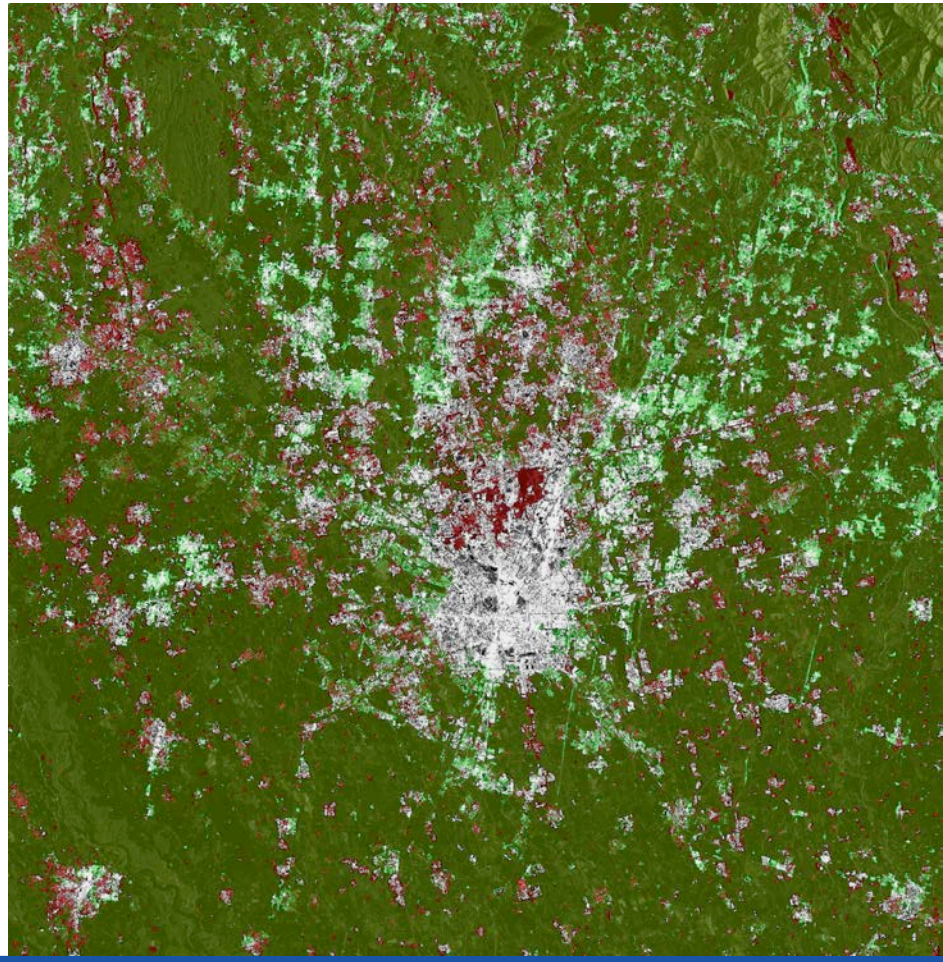
Preliminary Results



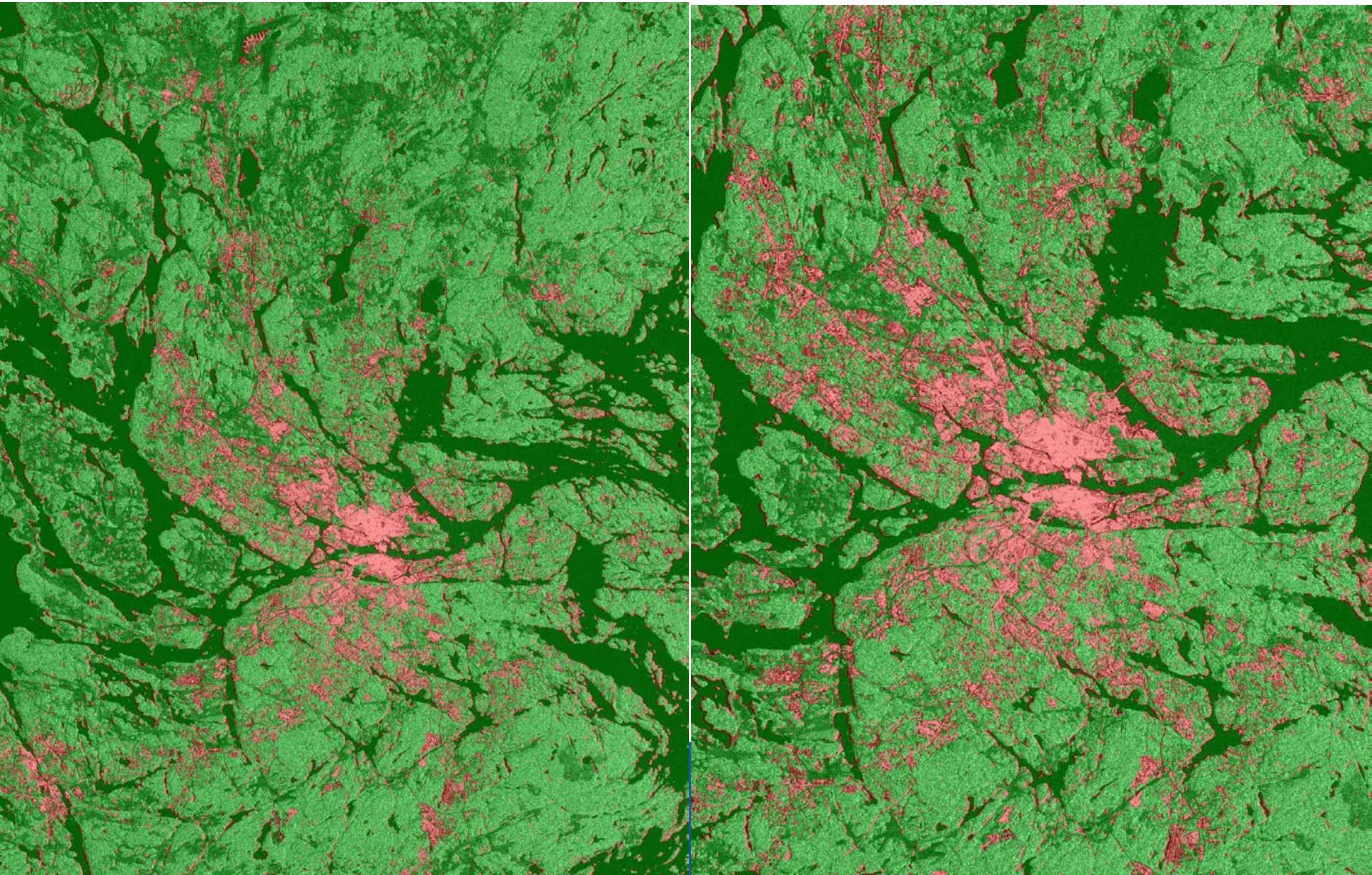


Preliminary Results



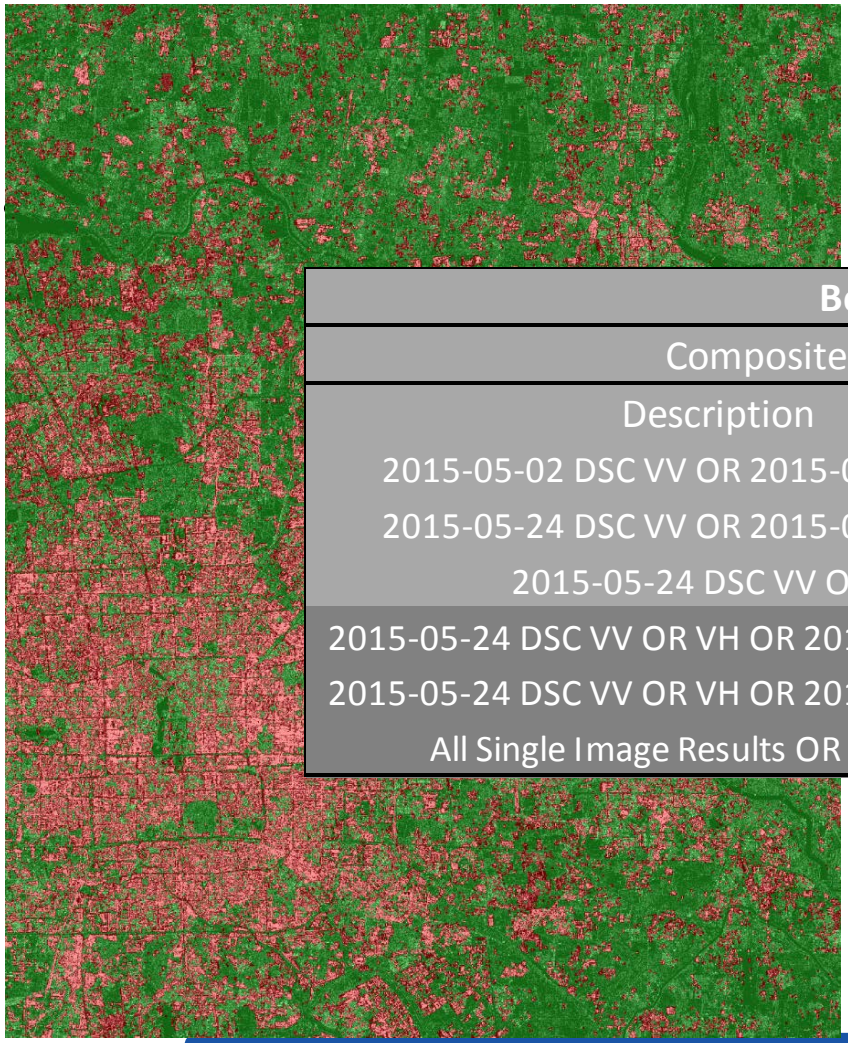


Preliminary Results

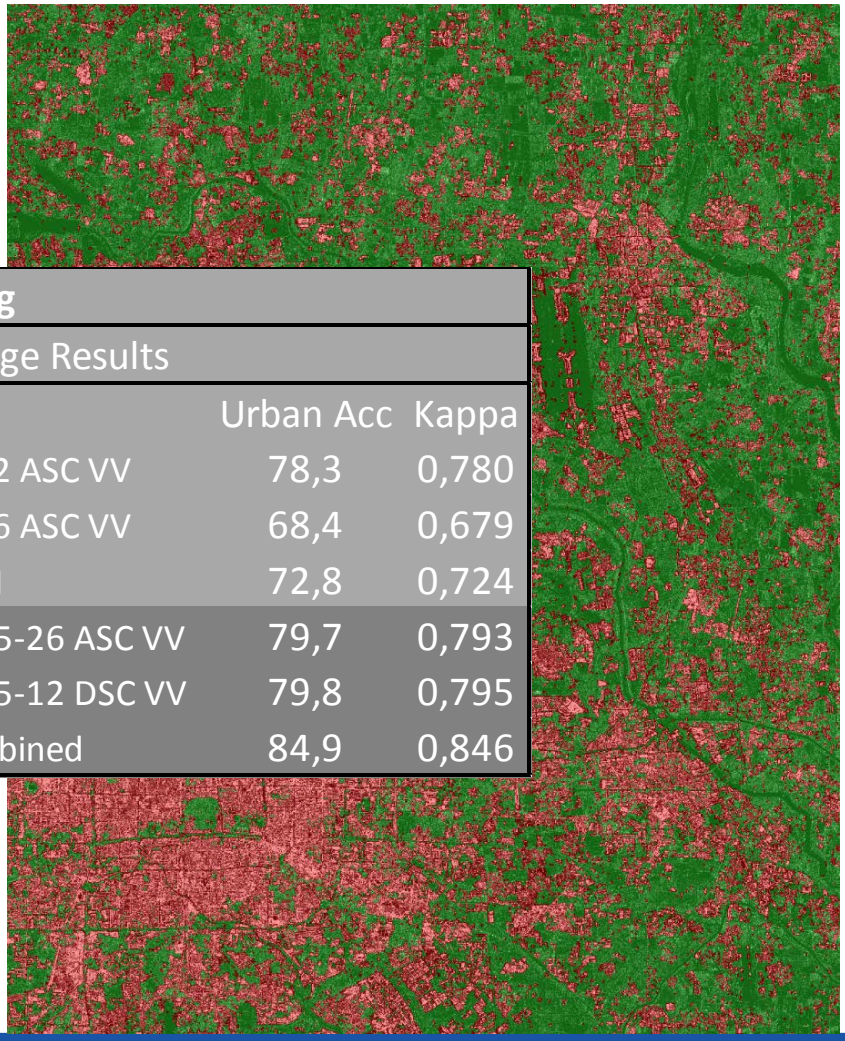


Preliminary Results

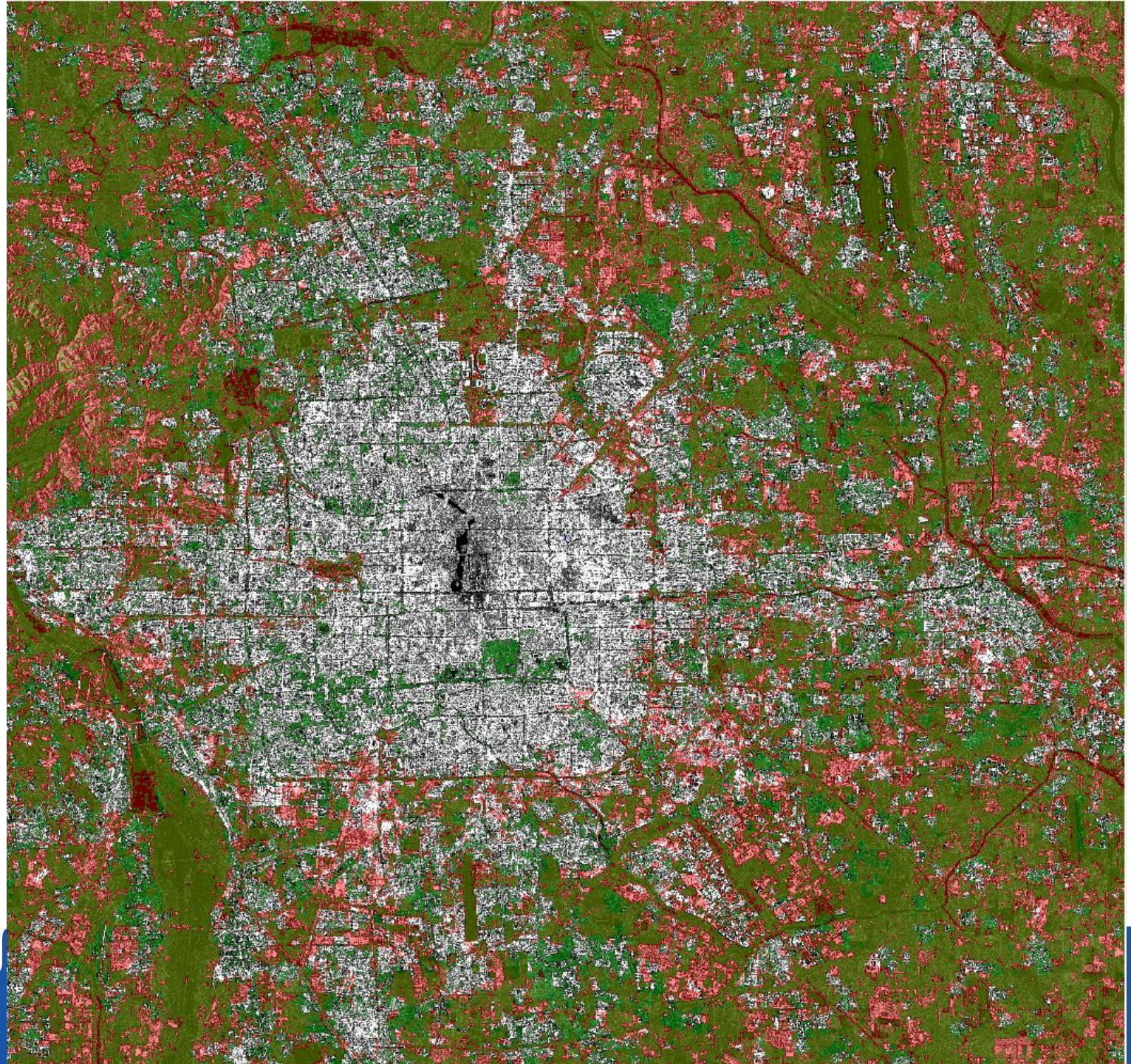
Beijing		
Composite Image Results		
Description	Urban Acc	Kappa
2015-05-02 DSC VV OR 2015-05-12 ASC VV	78,3	0,780
2015-05-24 DSC VV OR 2015-05-26 ASC VV	68,4	0,679
2015-05-24 DSC VV OR VH	72,8	0,724
2015-05-24 DSC VV OR VH OR 2015-05-26 ASC VV	79,7	0,793
2015-05-24 DSC VV OR VH OR 2015-05-12 DSC VV	79,8	0,795
All Single Image Results OR Combined	84,9	0,846



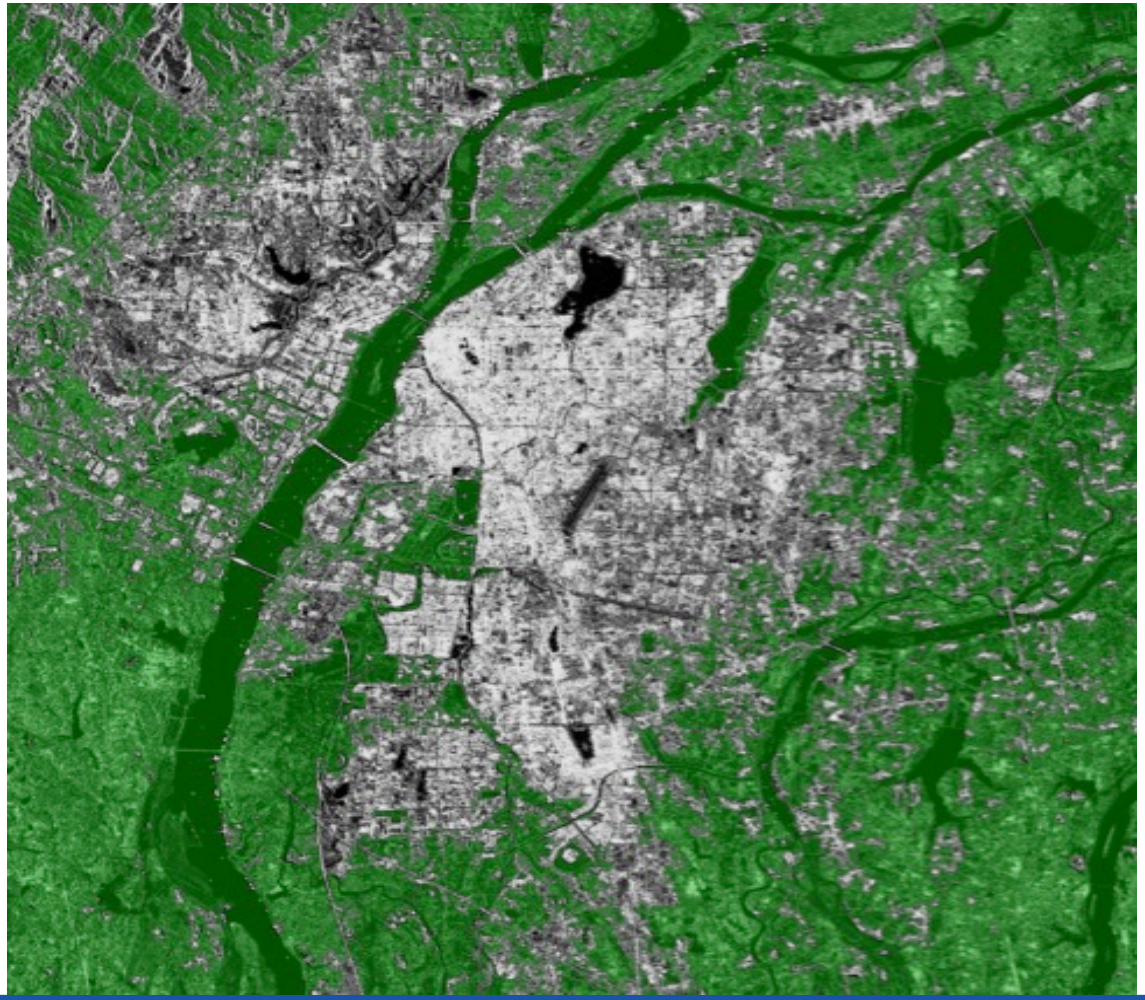
Beijing Pol + ASC + DSC



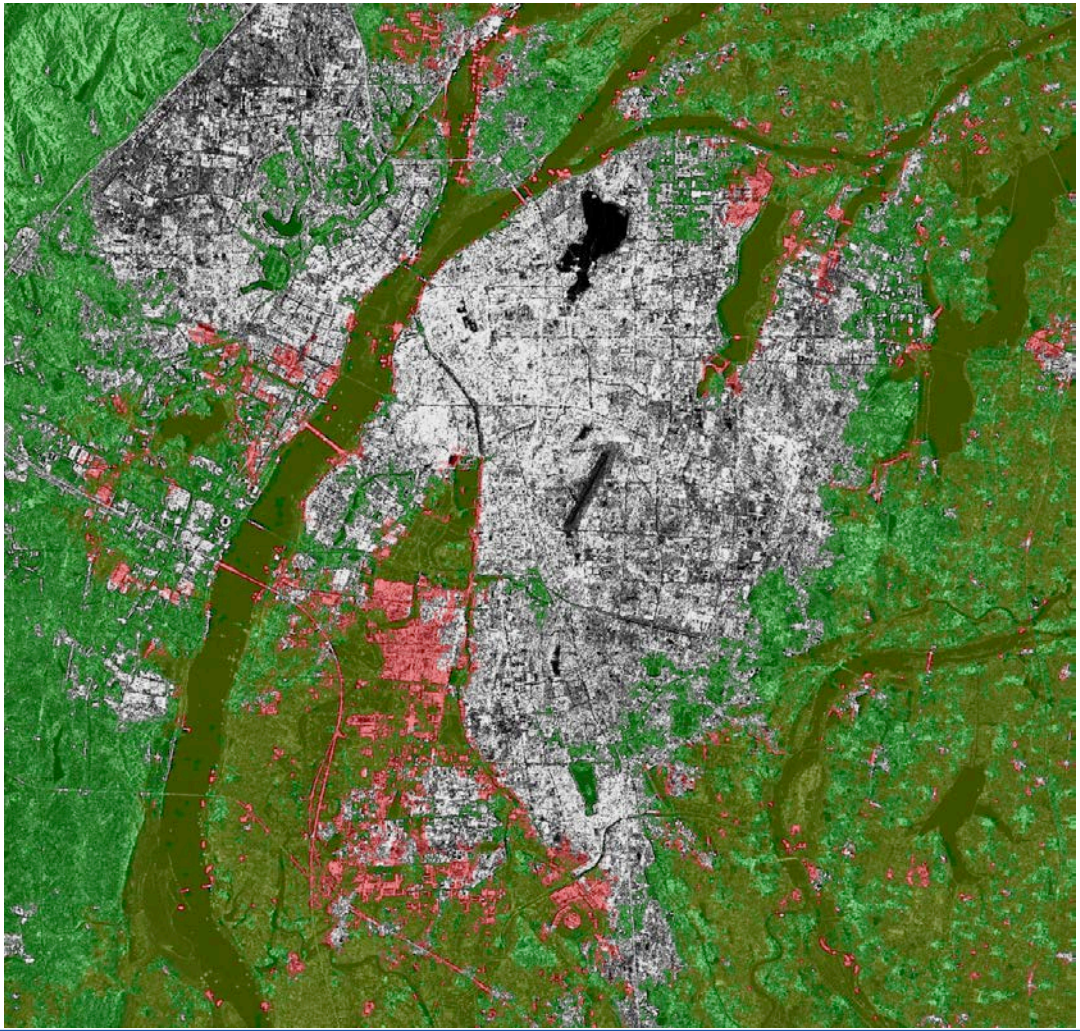
Beijing All Images Composite



Preliminary Results



Preliminary Results



Preliminary Results