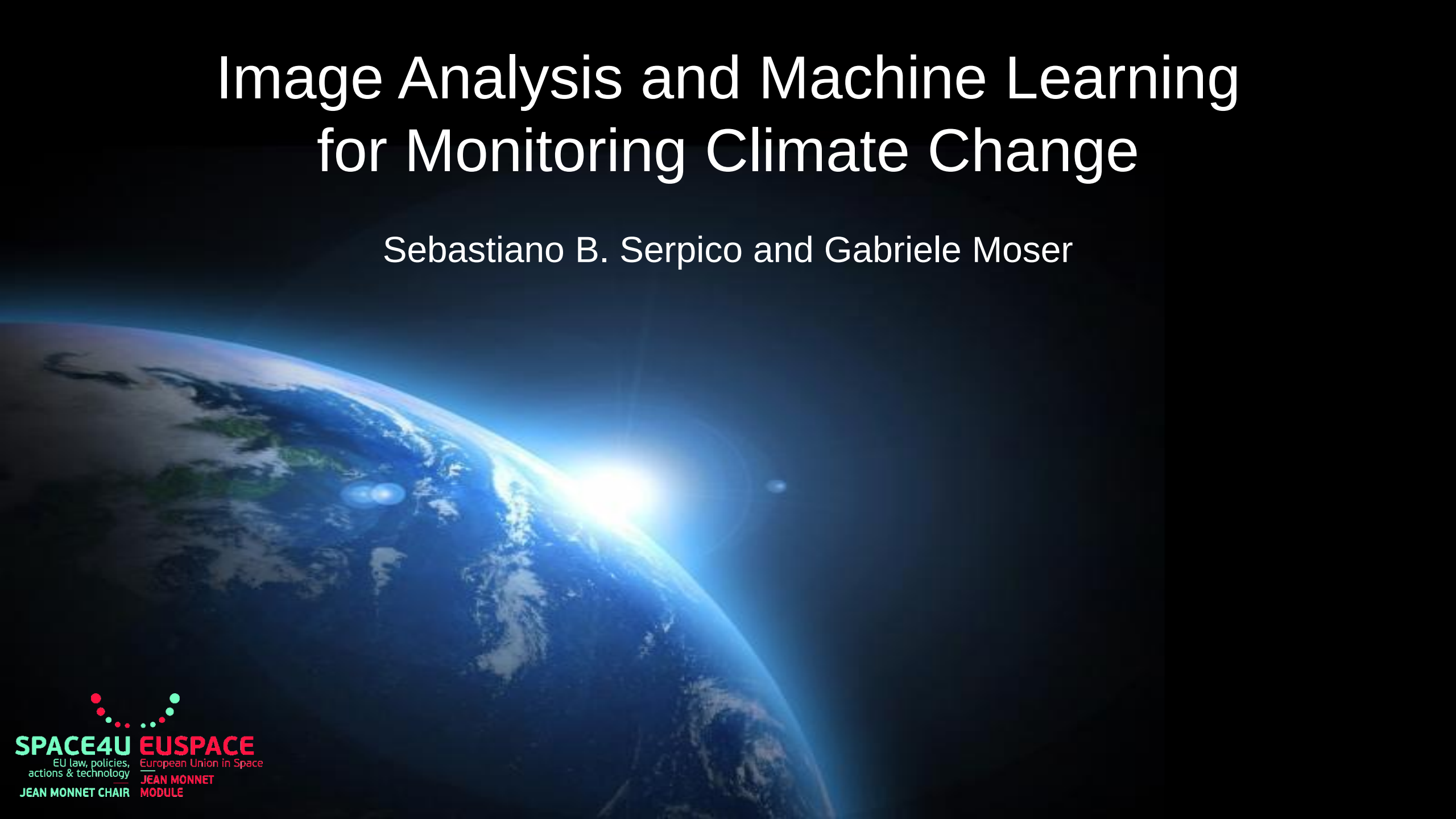
Image Analysis and Machine Learning for Monitoring Climate Change

Sebastiano B. Serpico and Gabriele Moser



SPACE4U EU law, policies, actions & technology
JEAN MONNET CHAIR

EUSPACE European Union in Space
JEAN MONNET MODULE

EO and Climate Change

Synoptic and time-repetitive view at the global, regional, and local scales

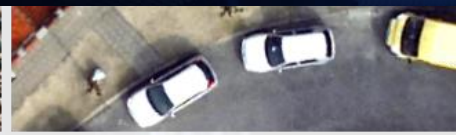
A **precious** source of data to monitor and mitigate the effects of **climate change**

But also a **huge amount of highly complex data**

To extract useful and quantitative information, **computer-based algorithms are necessary**

(d) 10 m

(e) 2 m



(f) 5 cm (da drone)

A Current Project: CCI+ HRLC

climate change initiative

→ HIGH RESOLUTION LAND COVER

esa

- Funded by the **European Space Agency**
- **Mapping land cover at subcontinental scale and its evolution along the past decades**, through satellite image analysis, to support climate change studies
- The project involves **research labs** in remote sensing and climatology as well as **private companies**

high resolution land cover cci

UNIVERSITÀ DEGLI STUDI DI TRENTO

FONDAZIONE BRUNO KESSLER

UNIVERSITÀ DEGLI STUDI DI GENOVA

UCLouvain

POLITECNICO MILANO 1863

e-geos AN ASI / TELESPAZIO COMPANY

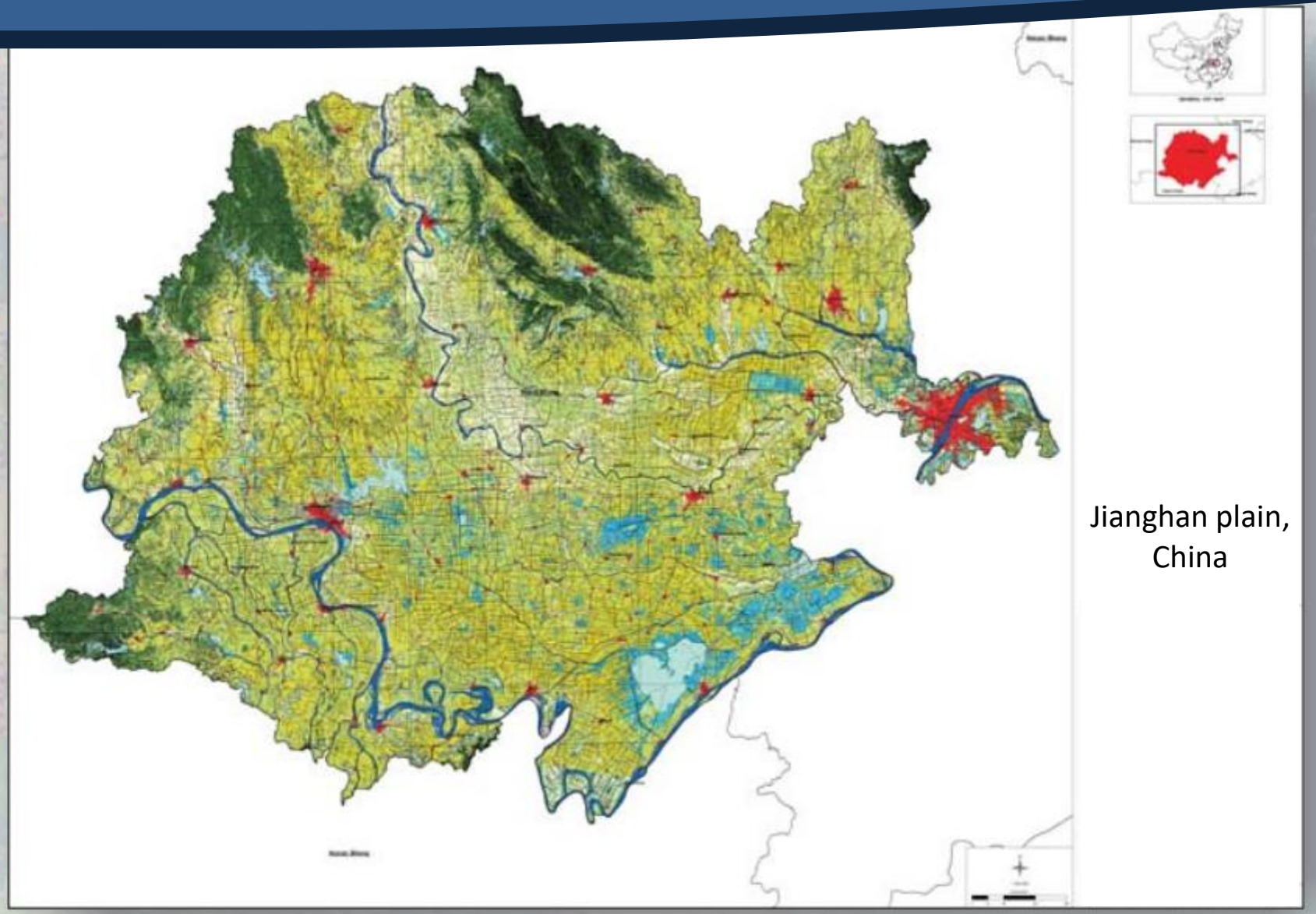
planetek italia

GeoVille

LSCE

CREAF

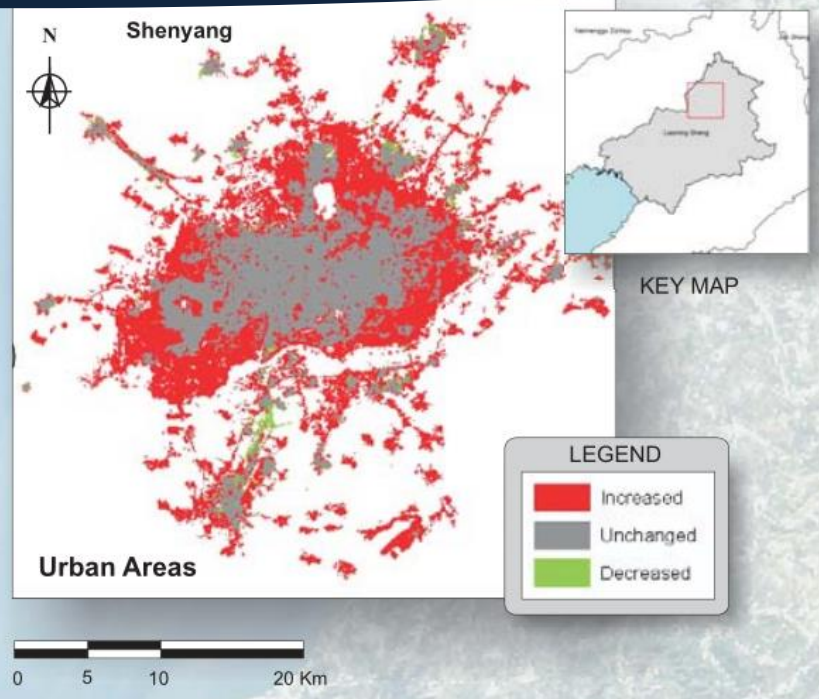
Land Cover from a Satellite

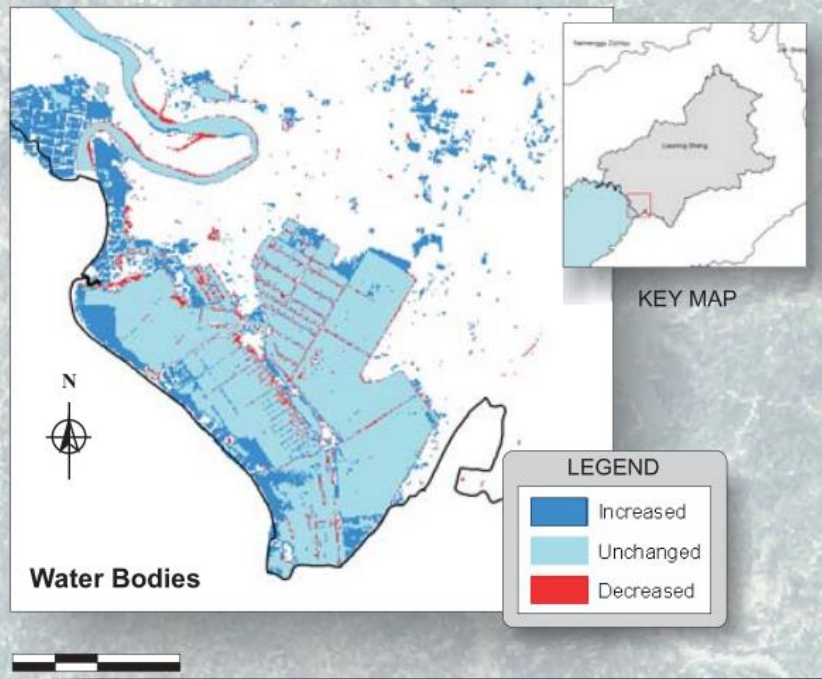


Jianghan plain, China

Land Cover Change from a Satellite

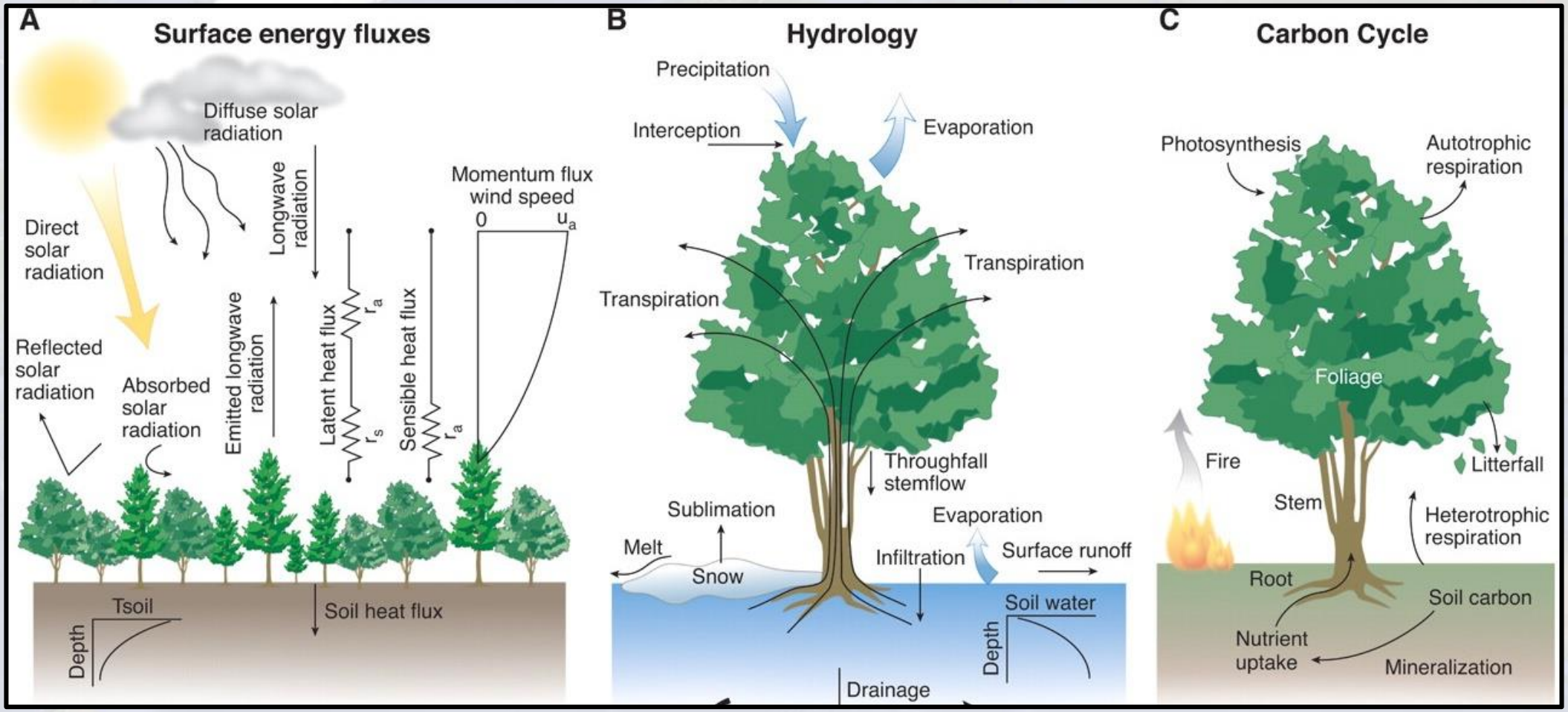
Temporal evolution of urban areas and water bodies





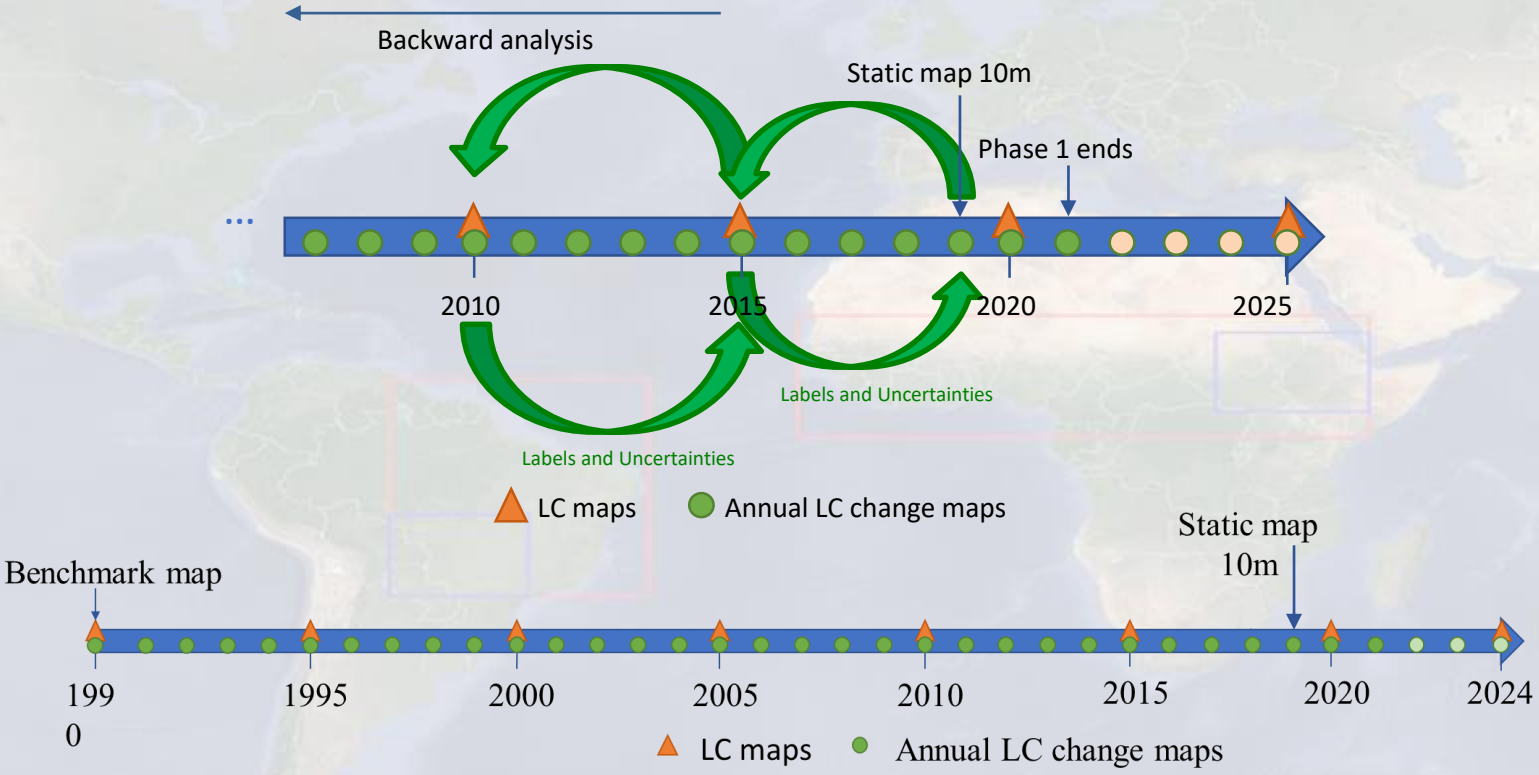
What's the Matter with Land Cover for Climate Change?

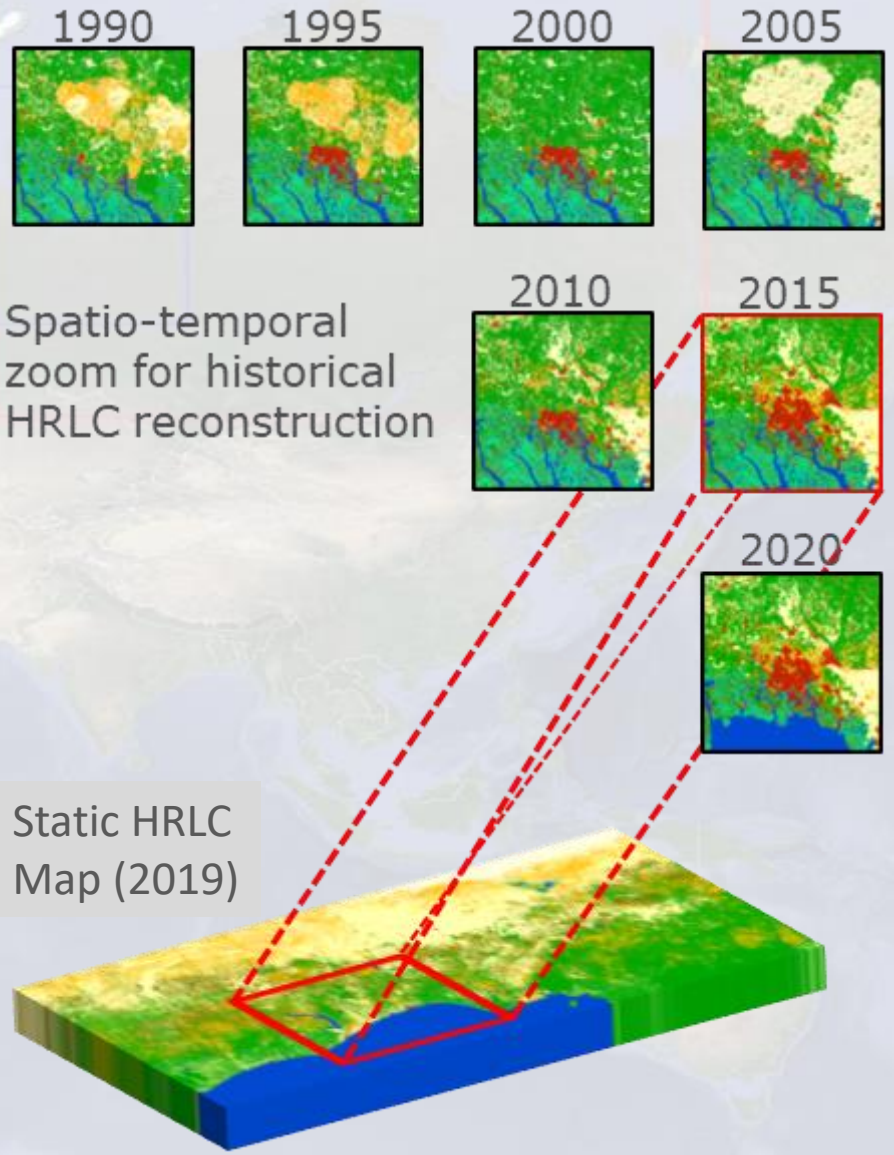
Land cover affects reflective (albedo) and aerodynamic properties, evapotranspiration, carbon storage, land surface temperature, and precipitation.



Project Products

- "Static" map of **land cover at the spatial resolution of 10 m in 2019**
- **"Historical" evolution of land cover since 1990**, observed every five years at the spatial resolution of 30 m, also assessing annual changes





UNIVERSITÀ DEGLI STUDI DI GENOVA

Study Areas

Regions characterized by **extreme climate conditions** or subject to **significant climate change in the past decades**

- Static map • 2019
- Historical evolution and change • 1990-2019

Impact of deforestation, forest fires, and agricultural development on water and carbon cycles

Impact of climate change on the shift of the forest-shrubs-grassland transition zone, and evolution of carbon storage in permafrost

Impact of climate change on drought, floods, and monsoon dynamic

About 35 million km²,
115 times the area of Italy

More than 400 terabytes
of images

(Geospatial) **Big Data**

DITEN

A few Ideas on the Methods

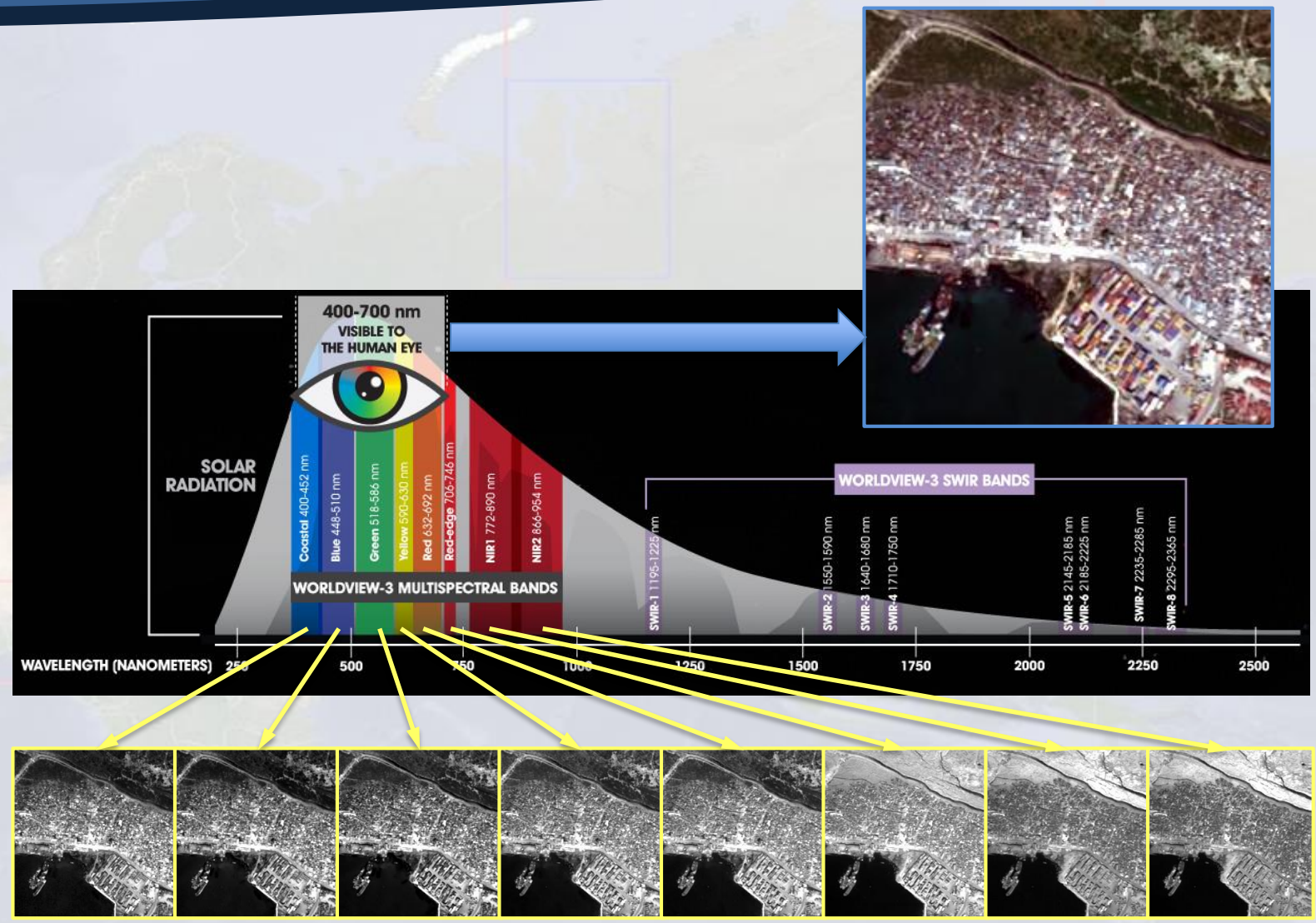
In general, satellite sensors collect **multiple measurements for each pixel**, for example in relation to different **wavelength ranges**.

The “measurements” taken by the human eye in the wavelength range of visible light determine what we usually call **“color.”**

A satellite sensor generally acquires **more measurements** than the human eye including at wavelengths outside the visible range (e.g., infrared, microwave).

All these measurements **(“spectral information”)** are relevant to identify the land cover of the portion of Earth surface associated with each pixel.

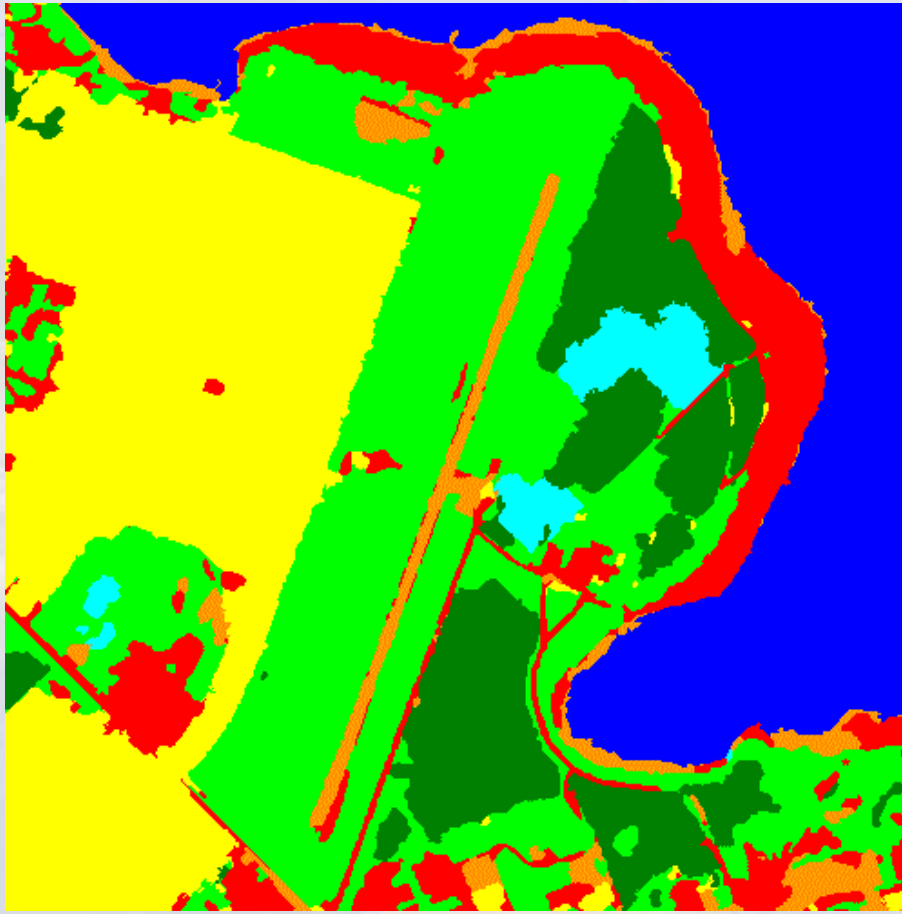
But it’s not enough…



A few Ideas on the Methods

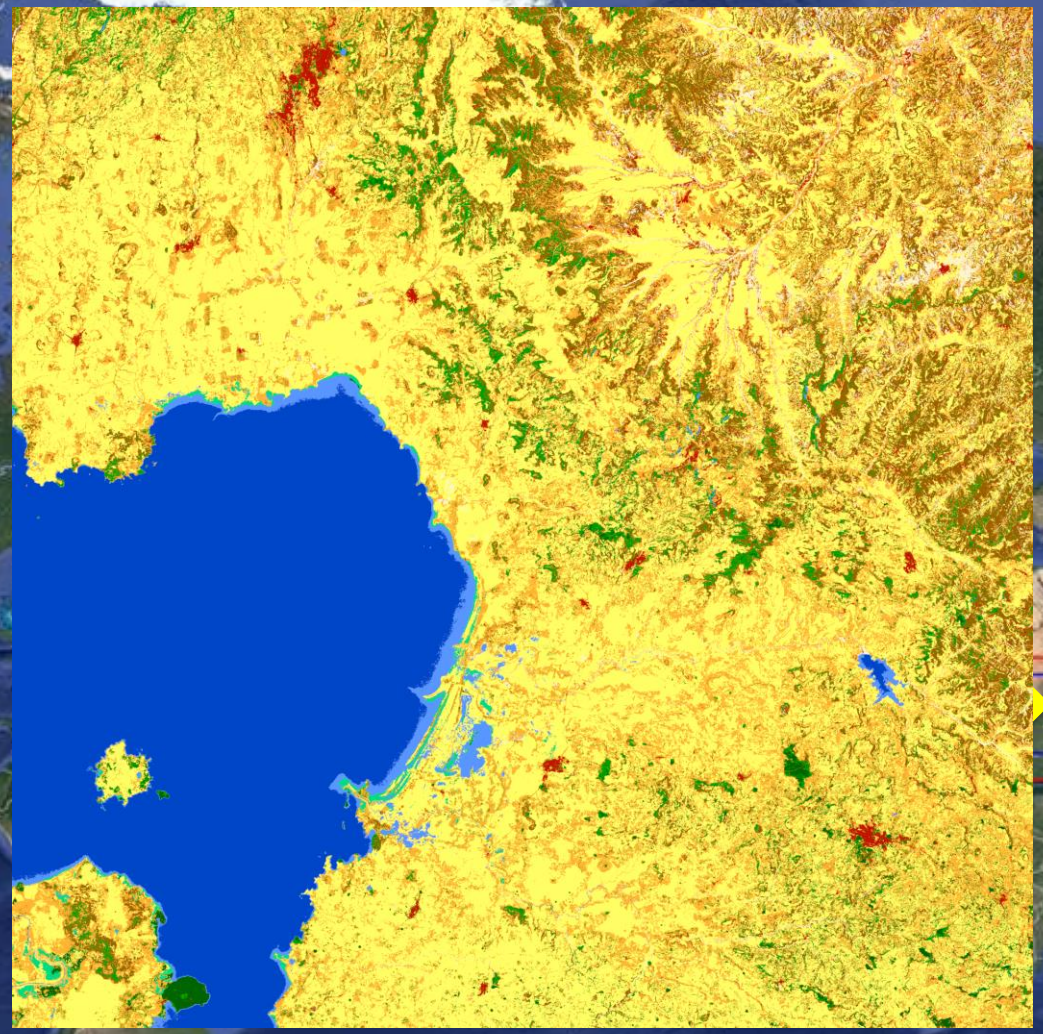
- Neighboring pixels in an image correspond to nearby portions of the Earth surface. Therefore, they are expected to be correlated **("spatial context").**
- If we do not take this into account and map land cover using only the spectral information, then the result can be **inaccurate and spatially irregular.**
- But if **we also use the spatial context…**

- Advanced **image processing** and **machine learning** methods model the spatial context and fuse it with the spectral information.
- This can be accomplished using advanced **probabilistic graphical models (e.g., Markov random fields)** and recently with **neural networks (deep learning)**.

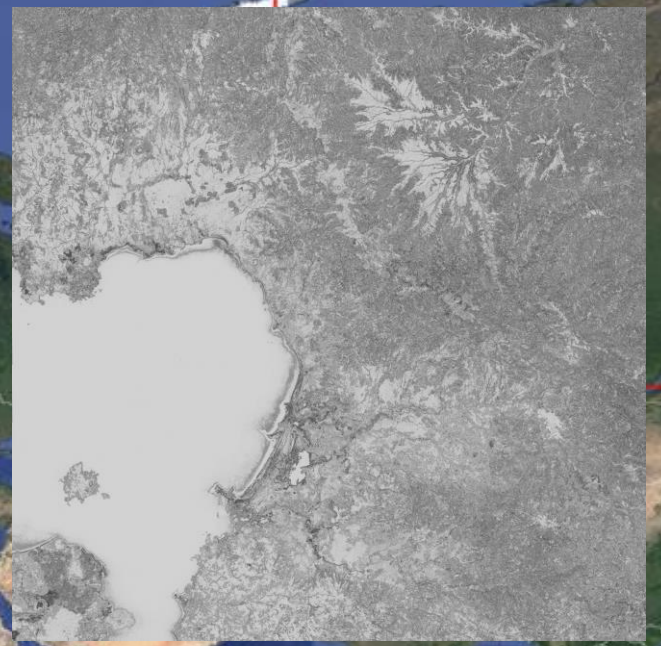


UNIVERSITÀ DEGLI STUDI DI GENOVA

Examples of Results: Africa



Classification map



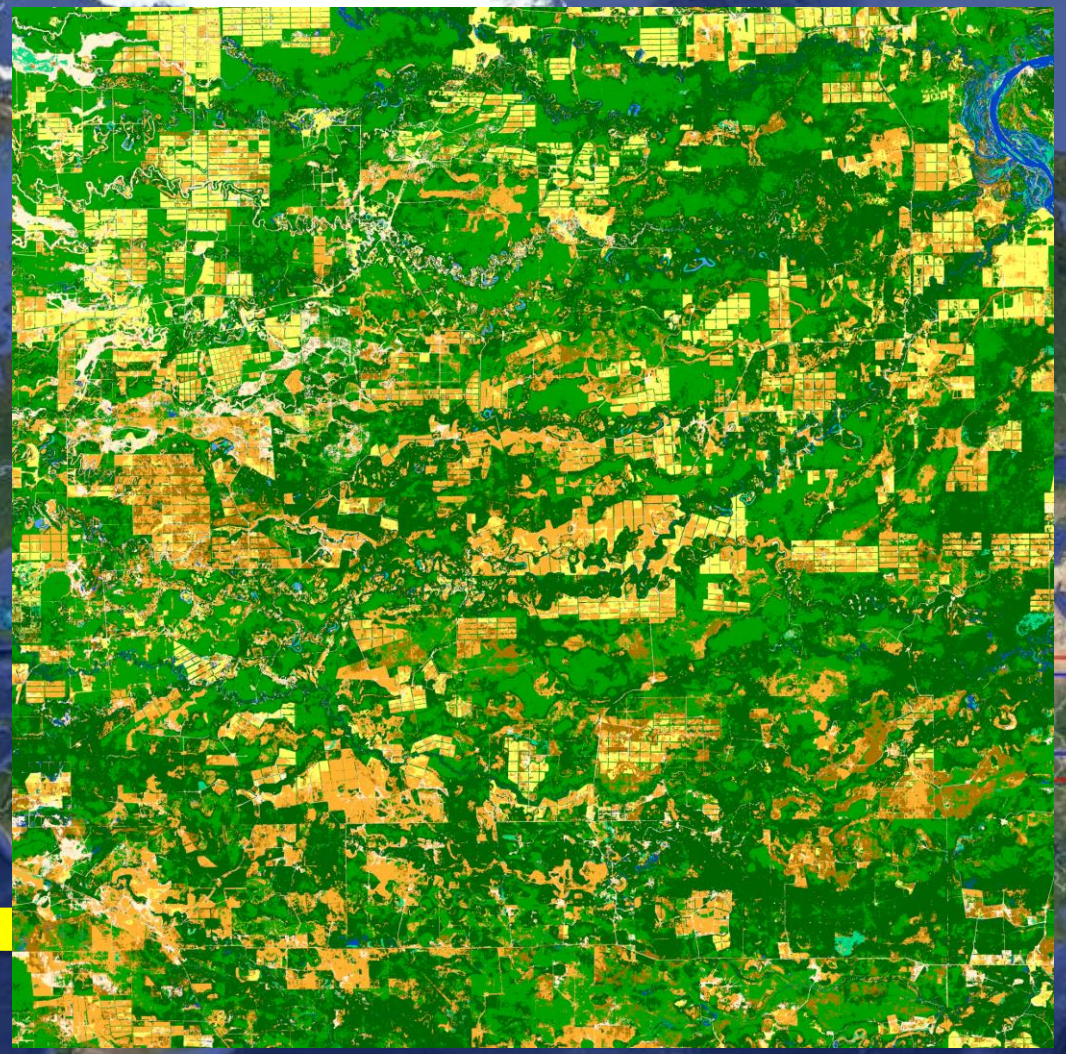
Confidence

CODE	DN	1st LEVEL
10	1	Tree cover evergreen broadleaf
20	2	Tree cover evergreen needleleaf
30	3	Tree cover deciduous broadleaf
40	4	Tree cover deciduous needleleaf
50	5	Shrub cover evergreen
60	6	Shrub cover deciduous
70	7	Grasslands
80	8	Croplands
90	9	Woody vegetation aquatic or regularly flooded
100	10	Grassland vegetation aquatic or regularly flooded
110	11	Lichens and Mosses
120	12	Bare areas
130	13	Built-up
140	14	Open Water seasonal
150	15	Open Water permanent
160	16	Permanent snow and/or ice

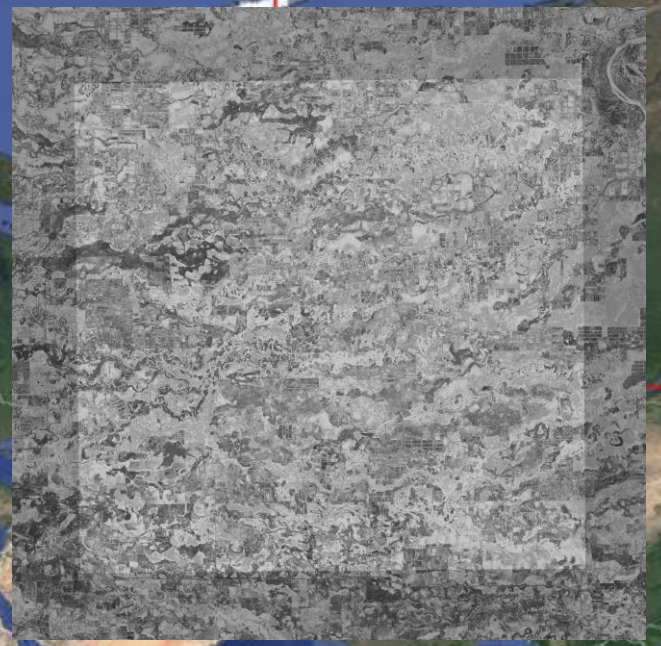
DITEN

UNIVERSITÀ DEGLI STUDI DI GENOVA

Examples of Results: Amazonia (1 of 2)



Classification map



Confidence

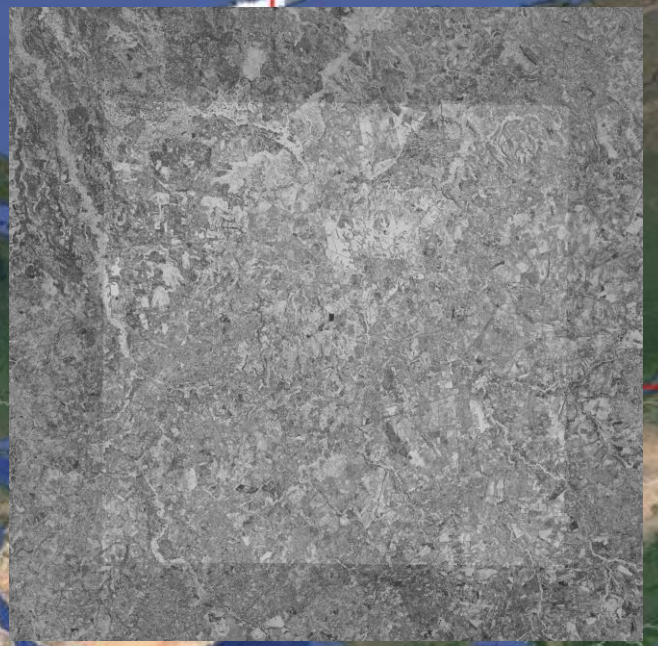
CODE	DN	1st LEVEL
10	1	Tree cover evergreen broadleaf
20	2	Tree cover evergreen needleleaf
30	3	Tree cover deciduous broadleaf
40	4	Tree cover deciduous needleleaf
50	5	Shrub cover evergreen
60	6	Shrub cover deciduous
70	7	Grasslands
80	8	Croplands
90	9	Woody vegetation aquatic or regularly flooded
100	10	Grassland vegetation aquatic or regularly flooded
110	11	Lichens and Mosses
120	12	Bare areas
130	13	Built-up
140	14	Open Water seasonal
150	15	Open Water permanent
160	16	Permanent snow and/or ice

DITEN

UNIVERSITÀ DEGLI STUDI DI GENOVA

Examples of Results: Amazonia (2 of 2)

Classification map



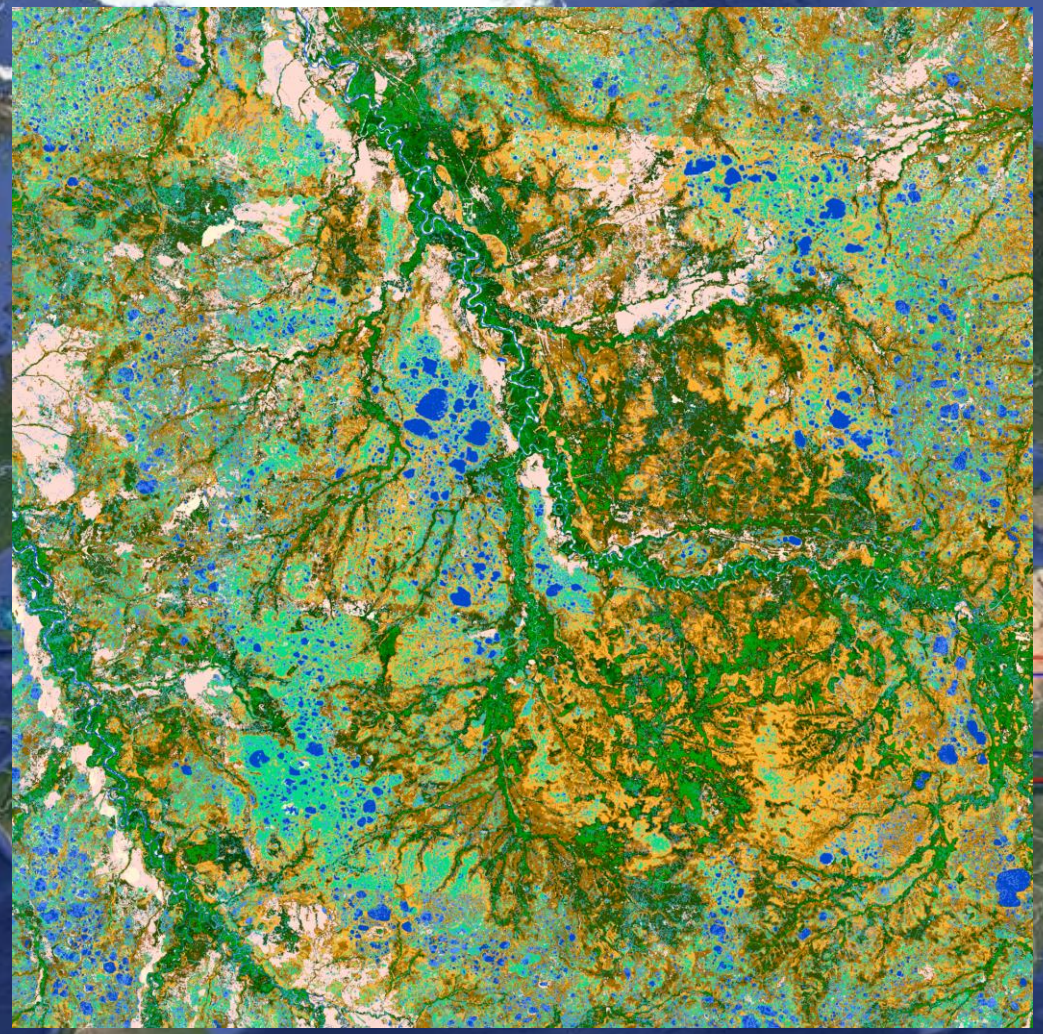
Confidence

CODE	DN	1st LEVEL
10	1	Tree cover evergreen broadleaf
20	2	Tree cover evergreen needleleaf
30	3	Tree cover deciduous broadleaf
40	4	Tree cover deciduous needleleaf
50	5	Shrub cover evergreen
60	6	Shrub cover deciduous
70	7	Grasslands
80	8	Croplands
90	9	Woody vegetation aquatic or regularly flooded
100	10	Grassland vegetation aquatic or regularly flooded
110	11	Lichens and Mosses
120	12	Bare areas
130	13	Built-up
140	14	Open Water seasonal
150	15	Open Water permanent
160	16	Permanent snow and/or ice

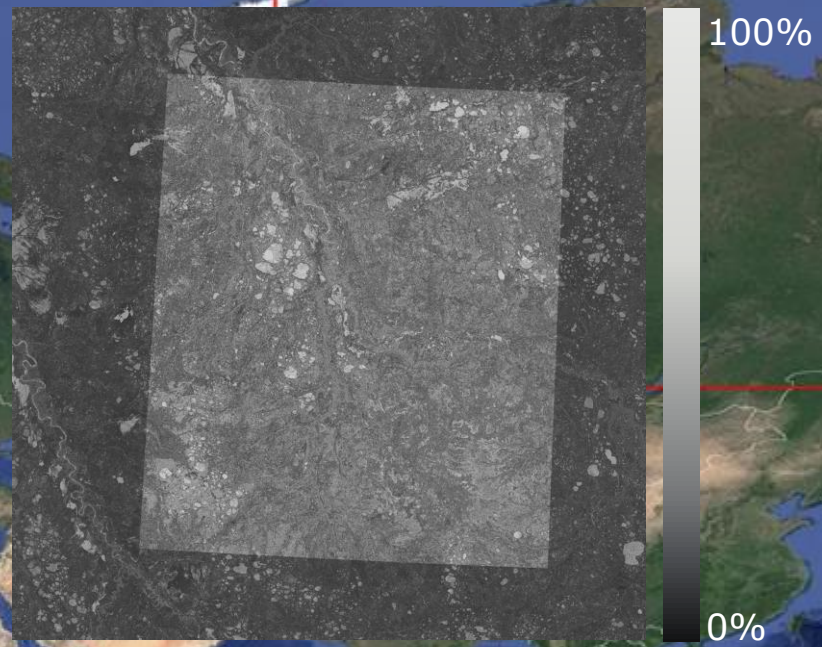
DITEN

UNIVERSITÀ DEGLI STUDI DI GENOVA

Examples of Results: Siberia



Classification map



Confidence

CODE	DN	1st LEVEL
10	1	Tree cover evergreen broadleaf
20	2	Tree cover evergreen needleleaf
30	3	Tree cover deciduous broadleaf
40	4	Tree cover deciduous needleleaf
50	5	Shrub cover evergreen
60	6	Shrub cover deciduous
70	7	Grasslands
80	8	Croplands
90	9	Woody vegetation aquatic or regularly flooded
100	10	Grassland vegetation aquatic or regularly flooded
110	11	Lichens and Mosses
120	12	Bare areas
130	13	Built-up
140	14	Open Water seasonal
150	15	Open Water permanent
160	16	Permanent snow and/or ice

DITEN

Conclusion

Space missions for Earth observation are unique tools to study, understand, and help mitigating **climate change**.

To benefit from the wealth of imagery that is made available by these missions, it is fundamental to develop advanced methods for information extraction, which are rooted in **image processing** and **machine learning**.

Current methodological approaches allow mapping land cover in an **automatic or semi-automatic manner** (to minimize the chance that the results are influenced by human subjectivity) and with the additional capability to evaluate **confidence, uncertainty, and accuracy.**


SPACE4U
EU law, policies, actions & technology
JEAN MONNET CHAIR
EUSPACE
European Union in Space
JEAN MONNET MODULE