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Urban Extraction Using Sentinel-1 SAR & Sentinel-2 MSI Dense Time Series with Google Earth Engine

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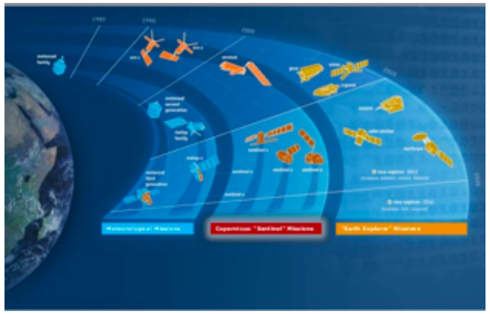
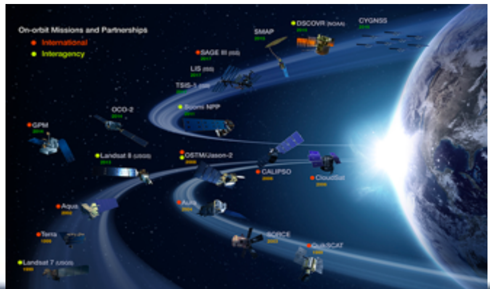
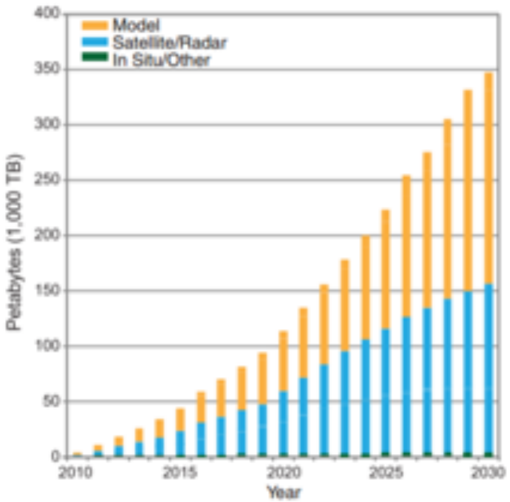
Where do we stand on Earth Observation?

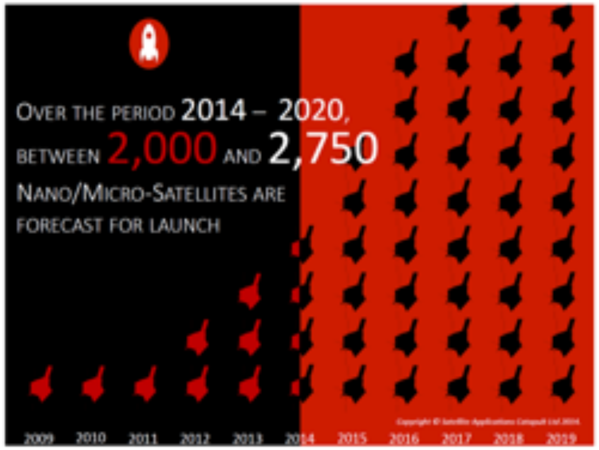
- Thanks to the fast growth of satellite technology we are moving forward into a new era of Earth Observation Big Data.
- Both National and International space agencies and innovative companies are supporting various EO programs acquiring huge amounts of data every day







Jonathan T. Overpeck et al, Science 2011



Earth Observation Big Data: Opportunities & Challenges

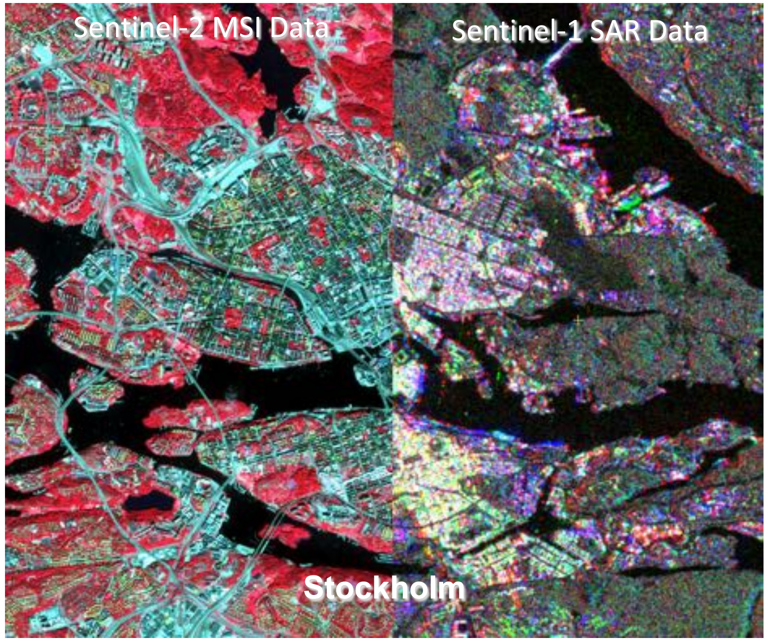
- **Opportunities**
  - Near-real time monitoring of phenomena affecting built and natural environment
  - Dense time series for analysis of global environmental changes
  - New possibility to deploy operational and reliable services

- **Challenges**
  - Exploit innovative computing infrastructure to handle, store and process the data
    - ESA Thematic Exploitation Platform
    - Copernicus Data and Information Access Services (DIAS)
    - Google Earth Engine
  - Develop new methods and algorithms to extract valuable information combining different sensors (i.e. Sentinels 1 &2) and products (i.e. DSMs, Land Cover Maps)
  - Integrate the analysis of the EO imagery with other geospatial big data (i.e. social media, ground sensors (i.e. GNSS), crowdsourced data)

Research Objectives

➢ **Why Urban Mapping?**

- Today, 54% of the world's population lives in urban areas.
- By 2050, the world is expected to add an additional 2.5 billion urban dwellers.
- Nearly 90 percent of the increase is concentrated in Asia and Africa.
- Urbanization has a significant impact on the environment



➢ **The objective** is to evaluate Sentinel-1 SAR and Sentinel-2 MSI dense time series for developing a global approach to continuously extract urban footprints to support smart and sustainable urban development.

- Follow-up of the EO4Urban Project Funded by the European Space Agency

Urban Dataset

Existing Urban Dataset:

- **DLR Global Urban Footprints (GUF):**
  - global coverage derived from TerraSAR-X data (90% of the data acquired in 2011-2012)
- **JRC Global Human Settlement Layer (GHSL):**
  - Global coverage derived from Landsat data (1975,1990,2000,2014)
- **JRC GHS Built-Up:**
  - Global coverage derived from Sentinel-1 data (2016 beta version)
- **Urban Layer in GlobeLand30:**
  - Global coverage derived from Landsat data
- **Atlas of Urban Expansion (NYU):**
  - 200 cities global, derived from Landsat data

GROUP ON EARTH OBSERVATIONS

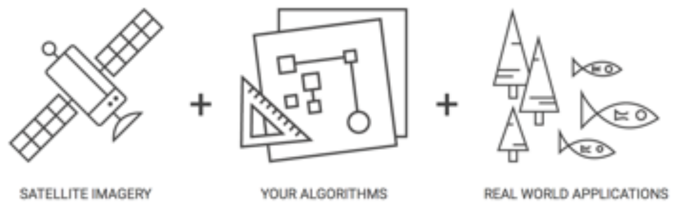
Google Earth Engine platform

Google Earth Engine (GEE) is a computing platform released by Google "for petabyte-scale scientific analysis and visualization of geospatial datasets":

- GEE enables researchers to **access geospatial information** and satellite imagery, for global and large scale remote sensing applications (**over than two petabytes** of geospatial data)

- GEE can be used to **perform geospatial analysis**, exploiting a dedicated HPC infrastructure, also running **user-developed software** through the **GEE API**

Google Earth Engine



ELSEVIER

Remote Sensing of Environment

Volume 202, 1 December 2017, Pages 18-27

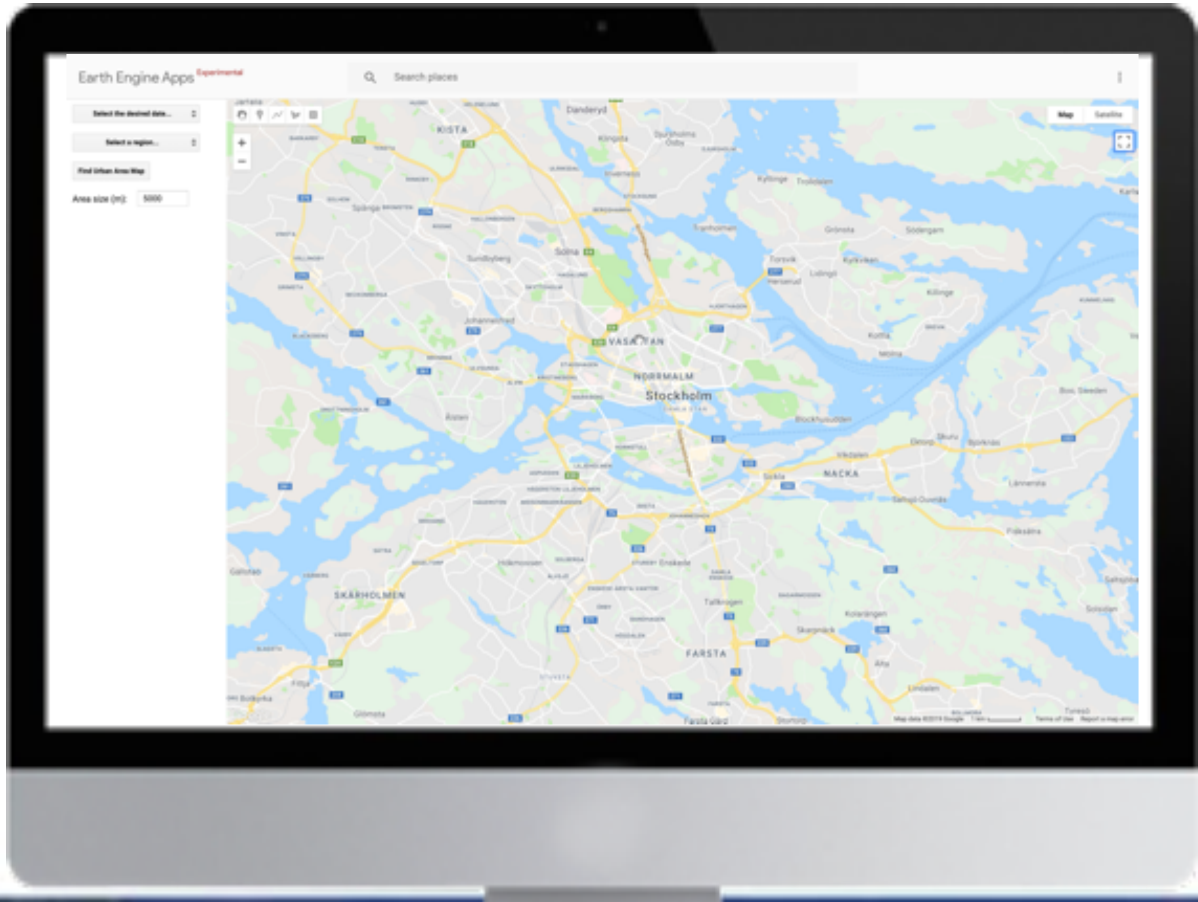
Google Earth Engine: Planetary-scale geospatial analysis for everyone

Noel Gorelick [a], Matt Hancher [b], Mike Dixon [b], Simon Ilyushchenko [b], David Thau [b], Rebecca Moore [b]

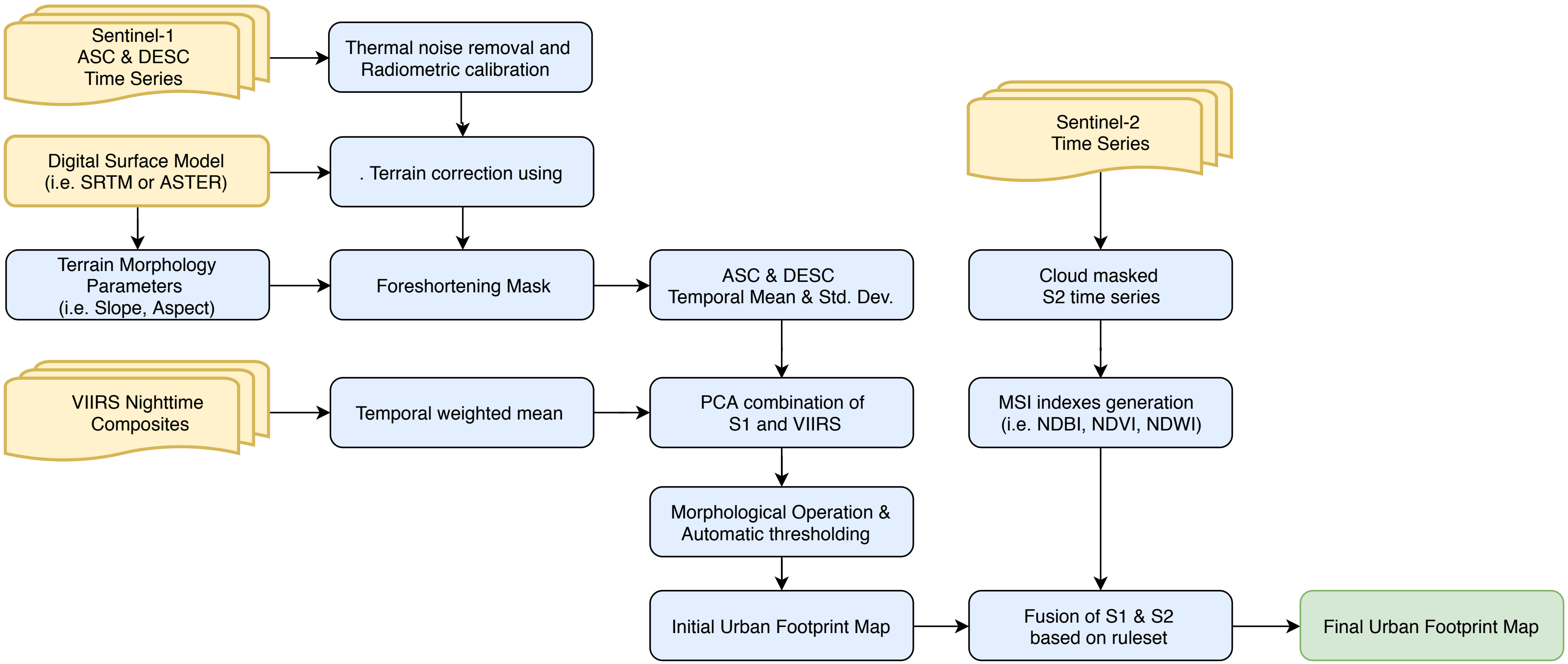
KTH GEE Urban Extractor

We developed a GEE App to compute the Urban Footprint using S1 & S2

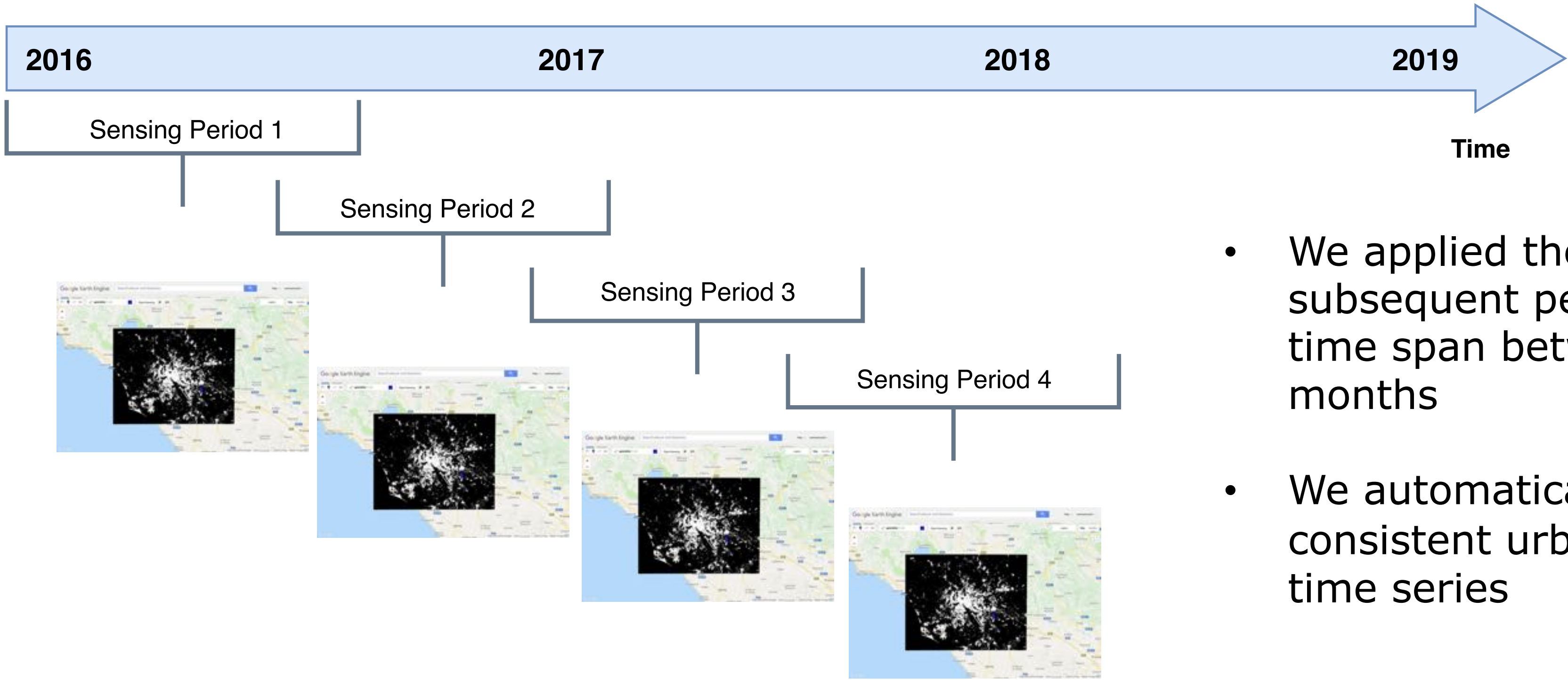
- Totally automatic workflow
- Selection of the AOI and the sensing period (i.e. Jan 2016 to June 2016)
- Fast processing exploiting the GEE potentialities (around 5/10 minutes for a city)
- Combine use of Sentinel-1 SAR and Sentinel-2 MSI data
- Free and open source software (first release expected June 2019)



KTH GEE Urban Extractor Workflow



KTH GEE Urban Extractor Workflow



- We applied the method on subsequent periods with a time span between 6-12 months

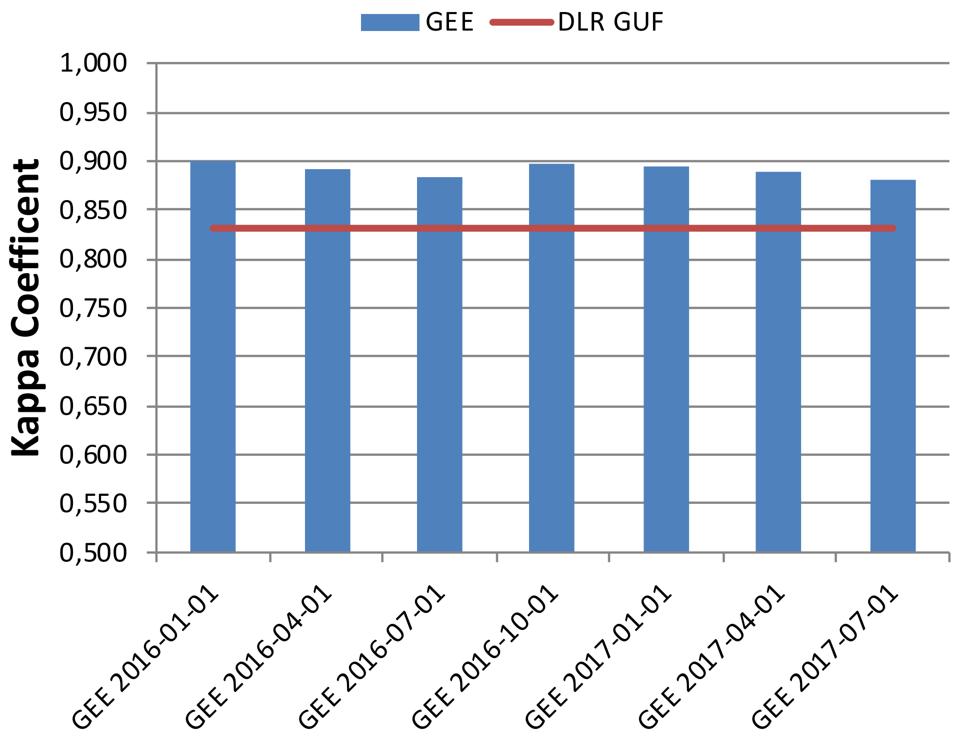
- We automatically generate consistent urban footprint time series

Validation Dataset

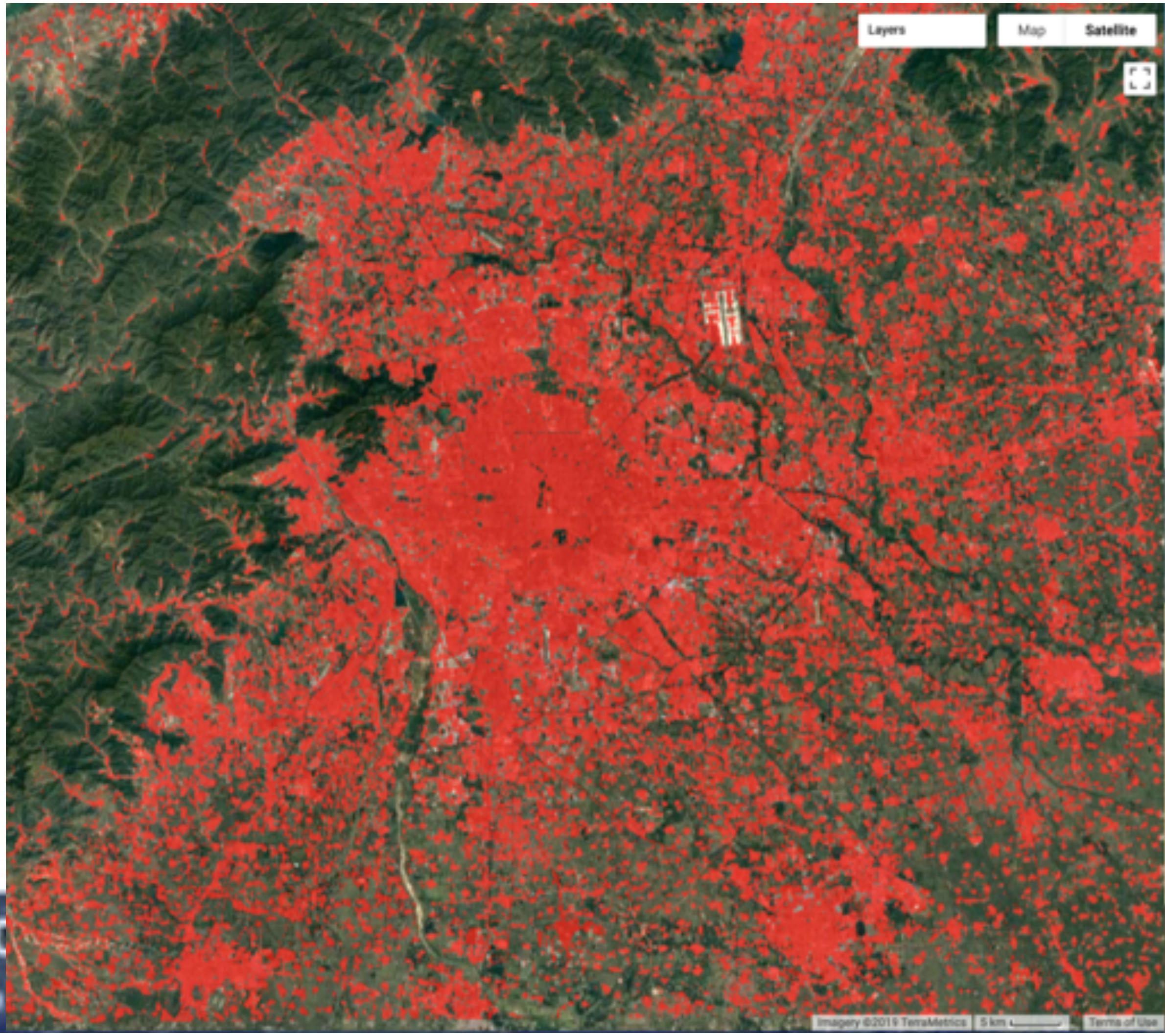
- Six cities investigated characterized by different morphology, climate and terrain
- > 10000 of validation points for each city (acquired in the ESA EO4Urban project)
- Comparison with available global datasets:
  - DLF GUF - Global Urban Footprint TerraSAR-X data acquired between 2011-2012
  - JRC GHS (Global Human Settlement)

Accuracy Assessment Beijing

Accuracy Assessment Beijing				
Dataset (start date)	Producers Accuracy (%)	Users Accuracy (%)	Overall Accuracy (%)	Kappa Coefficent
DLR GUF	87.86	94.91	91.567	0.831
JRC GHS	75.45	90.96	83.966	0.679
GEE 2016-01-01	99.20	91.48	94.974	0.900
GEE 2016-04-01	99.06	90.84	94.527	0.891
GEE 2016-07-01	99.24	90.12	94.175	0.884
GEE 2016-10-01	99.17	91.28	94.844	0.897
GEE 2017-01-01	99.08	91.10	94.693	0.894
GEE 2017-04-01	99.05	90.82	94.512	0.890
GEE 2017-07-01	98.76	90.15	93.984	0.880



Beijing Results



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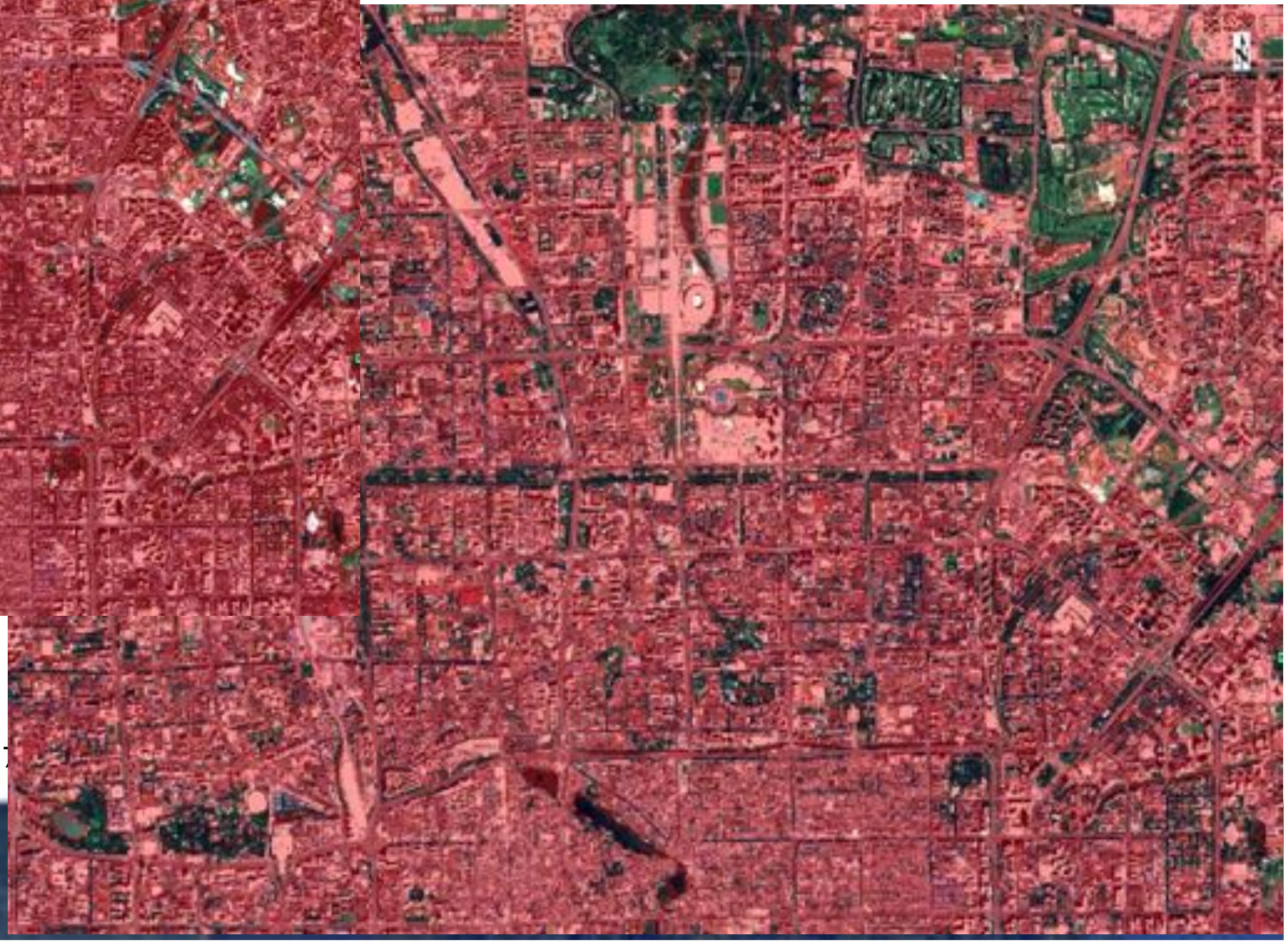


KTH GEE UE results 201

Beijing Results: Issues

KTH GEE UE results 2017

GUF results (2011-2012)

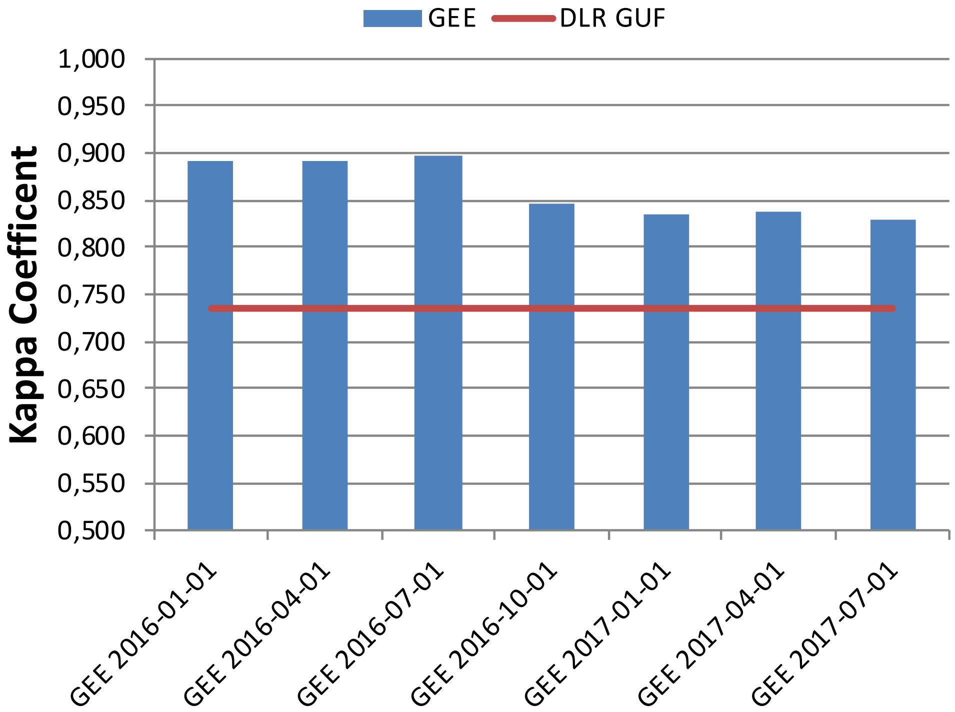
Beijing Results: Changes

KTH GEE UE results 2017

GUF results (2011-2012)

Accuracy Assessment Stockholm

Accuracy Assessment Stockholm				
Dataset (start date)	Producers Accuracy (%)	Users Accuracy (%)	Overall Accuracy (%)	Kappa Coefficent
DLR GUF	74.47	98.63	86.795	74.47
JRC GHS	93.02	91.95	92.481	93.02
GEE 2016-01-01	96.65	92.65	94.521	96.65
GEE 2016-04-01	96.75	92.76	94.629	96.75
GEE 2016-07-01	97.20	92.74	94.826	97.20
GEE 2016-10-01	91.77	92.82	92.382	91.77
GEE 2017-01-01	91.67	91.78	91.781	91.67
GEE 2017-04-01	91.85	91.83	91.889	91.85
GEE 2017-07-01	89.93	92.59	91.416	89.93



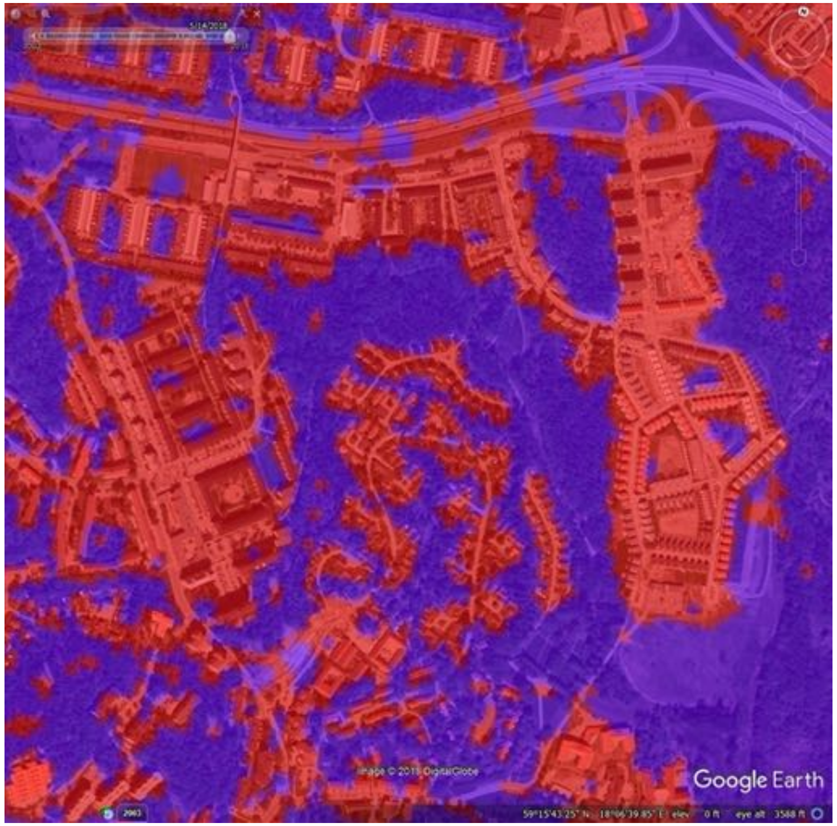
Stockholm Results

Stockholm Results

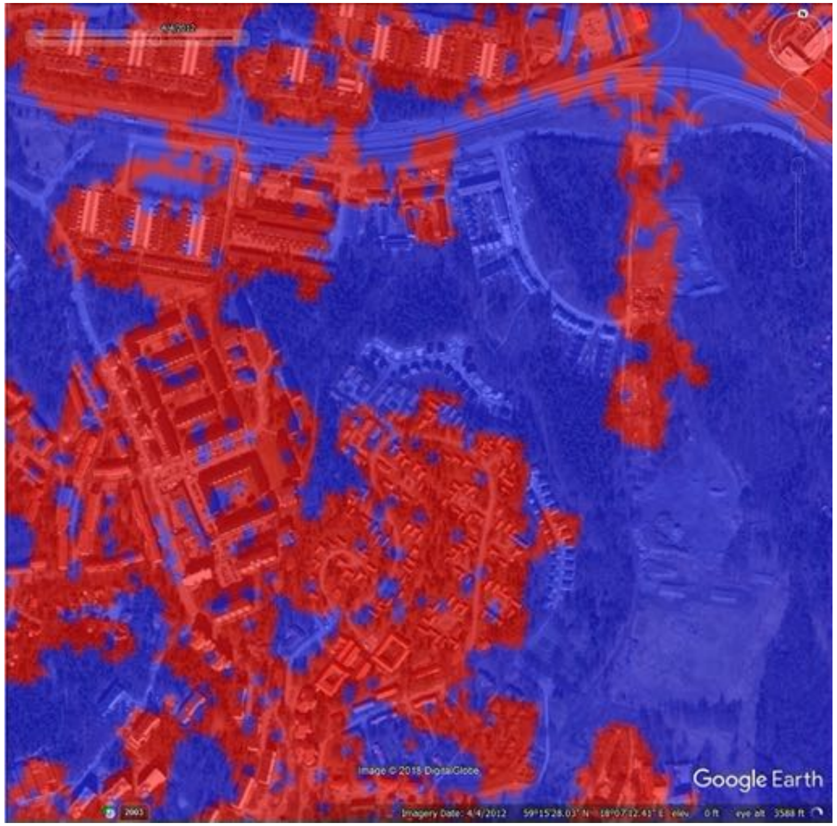
KTH GEE UE results 2016

GUF results (2011-2012)

Stockholm Results: Urban Changes



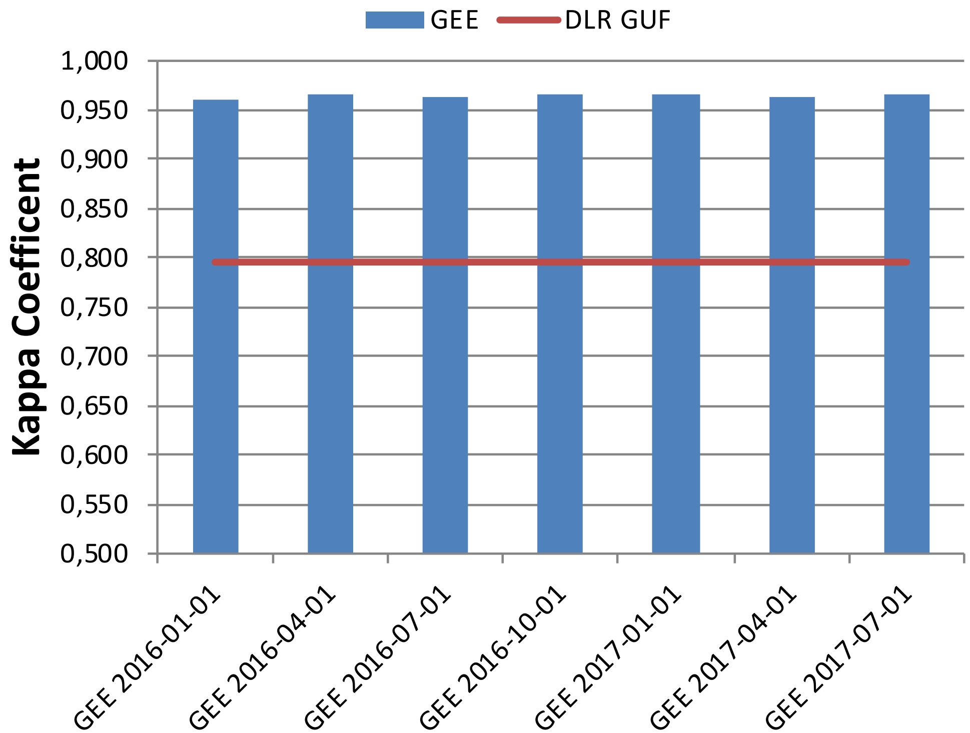
KTH GEE UE results 2017



GUF results (2011-2012)

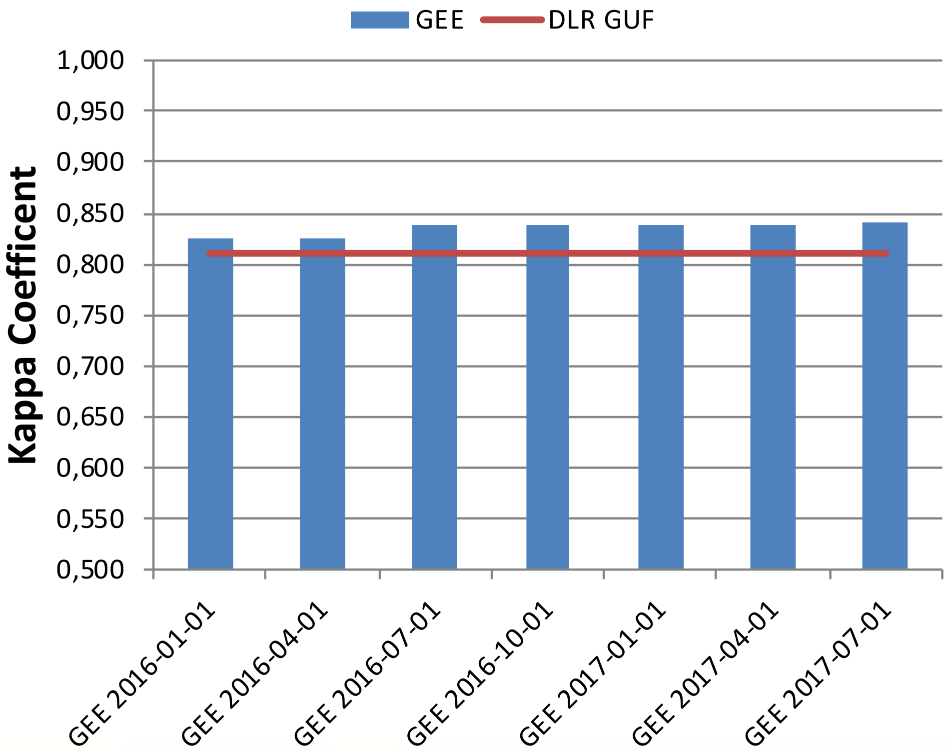
Accuracy Assessment Milano

Accuracy Assessment Milano				
Dataset (start date)	Producers Accuracy (%)	Users Accuracy (%)	Overall Accuracy (%)	Kappa Coefficent
DLR GUF	84.41	95.07	89.791	0.796
JRC GHS	70.41	87.43	80.146	0.603
GEE 2016-01-01	98.92	97.59	98.240	0.960
GEE 2016-04-01	99.18	97.46	98.300	0.966
GEE 2016-07-01	99.18	97.33	98.230	0.965
GEE 2016-10-01	99.14	97.41	98.250	0.965
GEE 2017-01-01	99.22	97.35	98.260	0.965
GEE 2017-04-01	99.26	97.20	98.200	0.964
GEE 2017-07-01	99.16	97.46	98.290	0.966



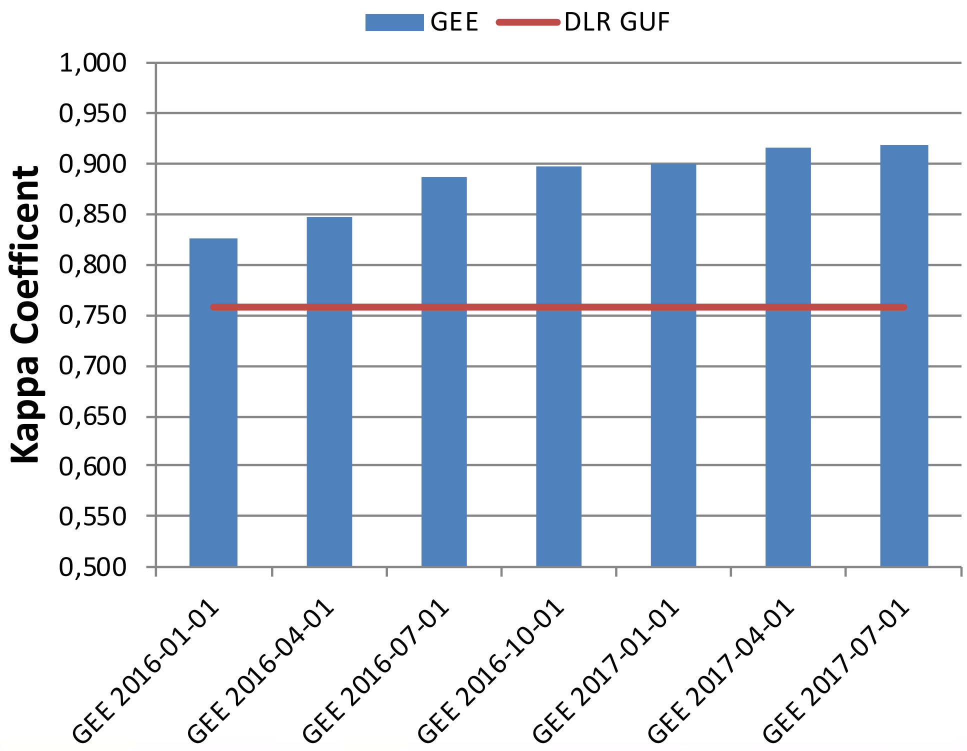
Accuracy Assessment New York

Accuracy Assessment New York				
Dataset (start date)	Producers Accuracy (%)	Users Accuracy (%)	Overall Accuracy (%)	Kappa Coefficent
DLR GUF	87.55	94.35	90.528	0.811
JRC GHS	93.14	87.17	88.987	0.778
GEE 2016-01-01	92.48	91.43	91.336	0.826
GEE 2016-04-01	92.50	91.49	91.378	0.827
GEE 2016-07-01	94.57	90.84	91.986	0.838
GEE 2016-10-01	93.68	91.42	91.911	0.837
GEE 2017-01-01	93.9	91.45	92.036	0.840
GEE 2017-04-01	93.92	91.4	92.011	0.839
GEE 2017-07-01	94.26	91.32	92.128	0.841



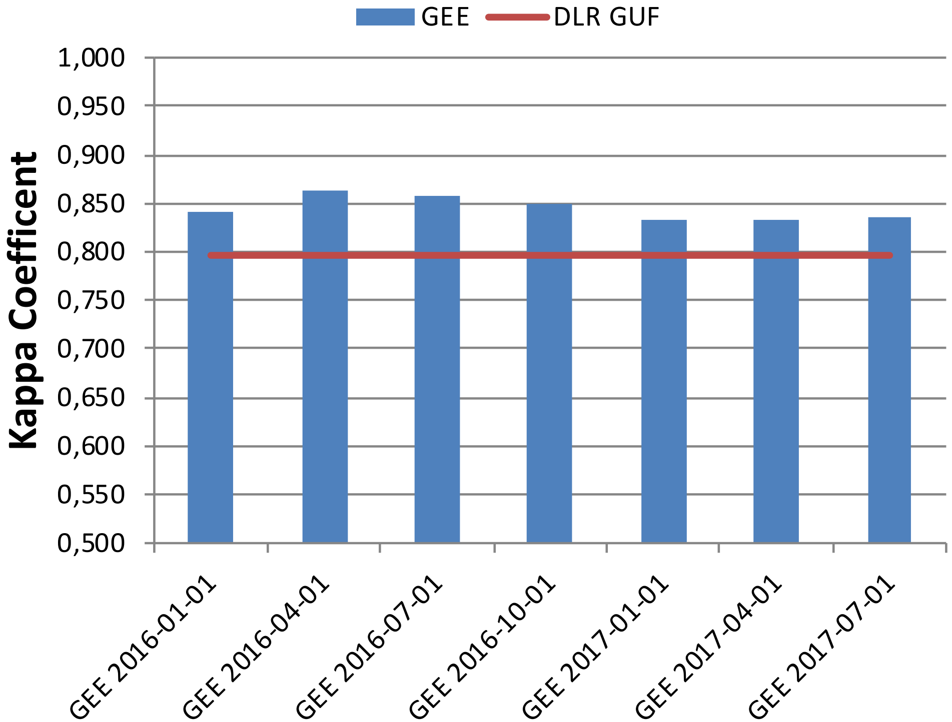
Accuracy Assessment Rio de Janeiro

Accuracy Assessment Rio de Janeiro				
Dataset (start date)	Producers Accuracy (%)	Users Accuracy (%)	Overall Accuracy (%)	Kappa Coefficent
DLR GUF	78.72	96.57	87.873	0.758
JRC GHS	63.29	93.66	79.516	0.590
GEE 2016-01-01	99.14	85.75	91.269	0.825
GEE 2016-04-01	98.98	87.51	92.370	0.847
GEE 2016-07-01	98.92	90.67	94.325	0.886
GEE 2016-10-01	98.76	91.67	94.854	0.897
GEE 2017-01-01	98.58	92.17	95.067	0.901
GEE 2017-04-01	98.10	93.89	95.827	0.917
GEE 2017-07-01	97.75	94.37	95.929	0.919



Accuracy Assessment Mexico City

Accuracy Assessment Mexico City				
Dataset (start date)	Producers Accuracy (%)	Users Accuracy (%)	Overall Accuracy (%)	Kappa Coefficent
DLR GUF	80.70	98.70	89.819	0.796
JRC GHS	60.52	97.05	79.340	0.587
GEE 2016-01-01	93.77	90.16	92.083	0.842
GEE 2016-04-01	94.17	92.18	93.088	0.862
GEE 2016-07-01	95.40	90.71	92.813	0.856
GEE 2016-10-01	96.57	89.15	92.408	0.848
GEE 2017-01-01	97.19	87.41	91.593	0.832
GEE 2017-04-01	97.58	87.17	91.608	0.832
GEE 2017-07-01	97.53	87.49	91.793	0.836



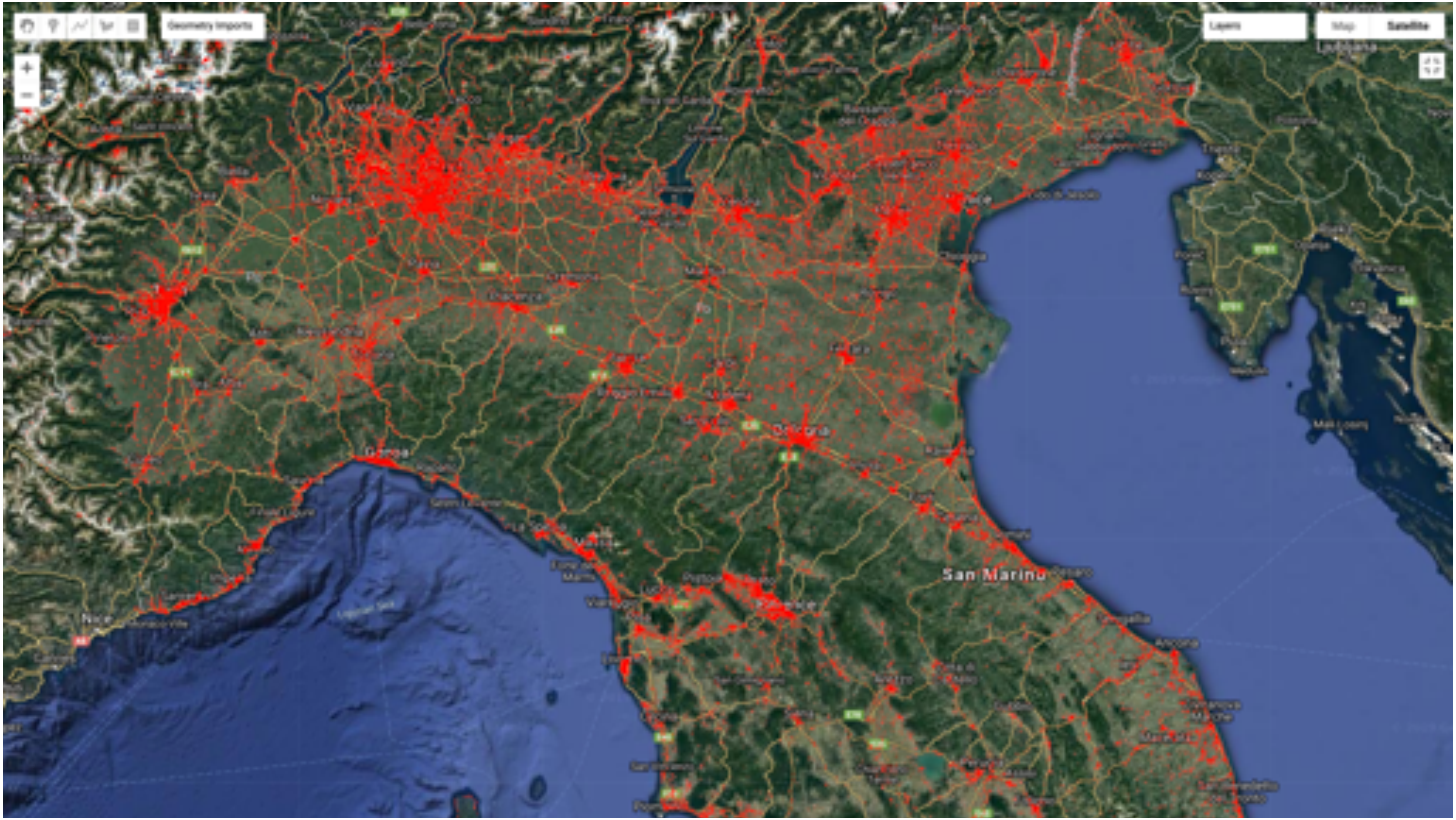
Conclusions & Future Prospects

The developed method is able to:

- achieved good results (k > 80%) in the different tested cities exploiting the fusion of S1 & S2 data
- produce urban footprint time series exploiting the processing capabilities of GEE

Next steps:

- Applied the method for large scale urban mapping and improve the accuracy assessment using other reference data
- Investigate the generated urban footprint time series to track the changes and improve the overall accuracy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