SUREDOS24
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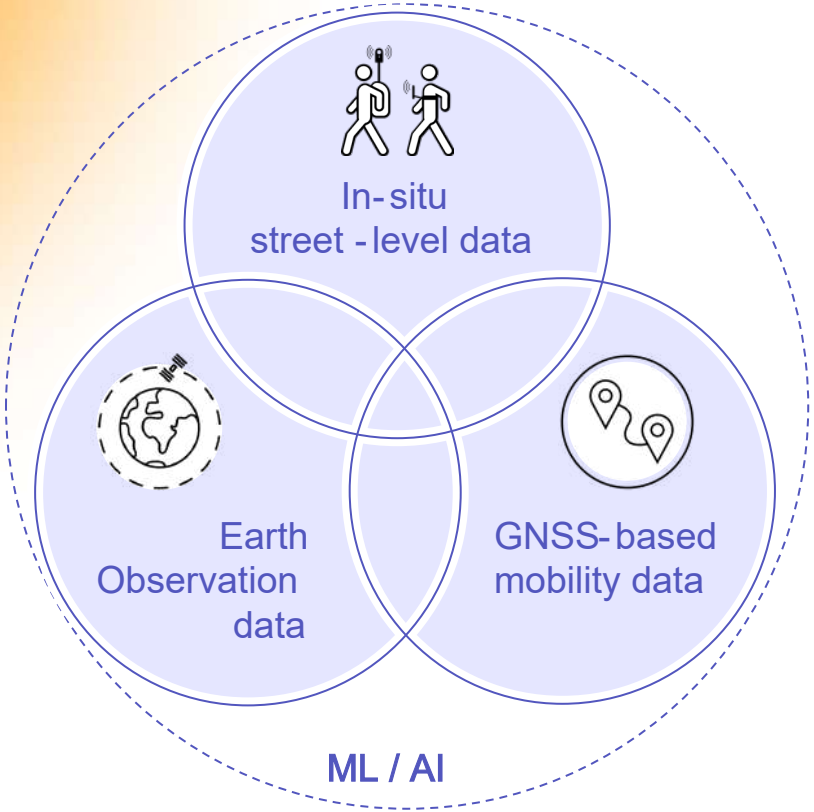
Enhancing Night-Time Light Imagery for Sustainable Development: the SupR-NTL Project

Implementing a scalable system for building Super-Resolution NightTime Light imagery to Assess Electricity Access in South-East Asia and Sub-Saharan Africa

MindEarth

www.mindearth.ai

About MindEarth



MindEarth operates in the field of location intelligence and human remote sensing, generating and combining data from first-party street-view imagery, Earth Observation products and mobility data using artificial intelligence.

The SupR-NTL project

Super-Resolution NightTime Light

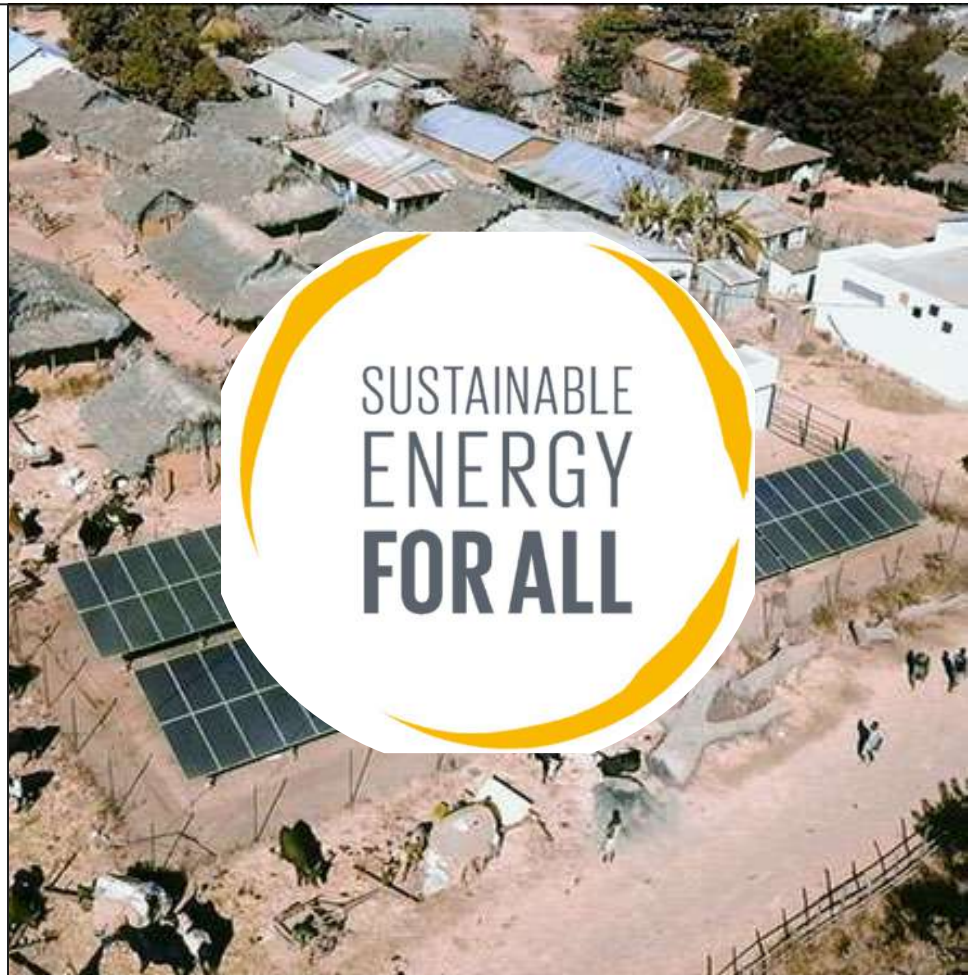
FUTURE EO-1 SEGMENT 2
OPEN CALL FOR PROPOSAL
FOR EO INNOVATION
Fast Innovative Action

Developing a robust and scalable system based on **Deep Neural Networks** for generating **SR-NTL imagery at 130m resolution**, to be used for the production of **high-resolution electricity access maps** at the **large scale**.

End User

Sustainable Energy for All (SEforAll)

- International organisation launched in 2011 by former UN Secretary-General Ban Ki-moon;
- Partnerships with UN, private sector, governments, and civil society to support SDG7;
- Assistance in energy transition, renewable energy projects, energy efficiency and local carbon markets.



Background

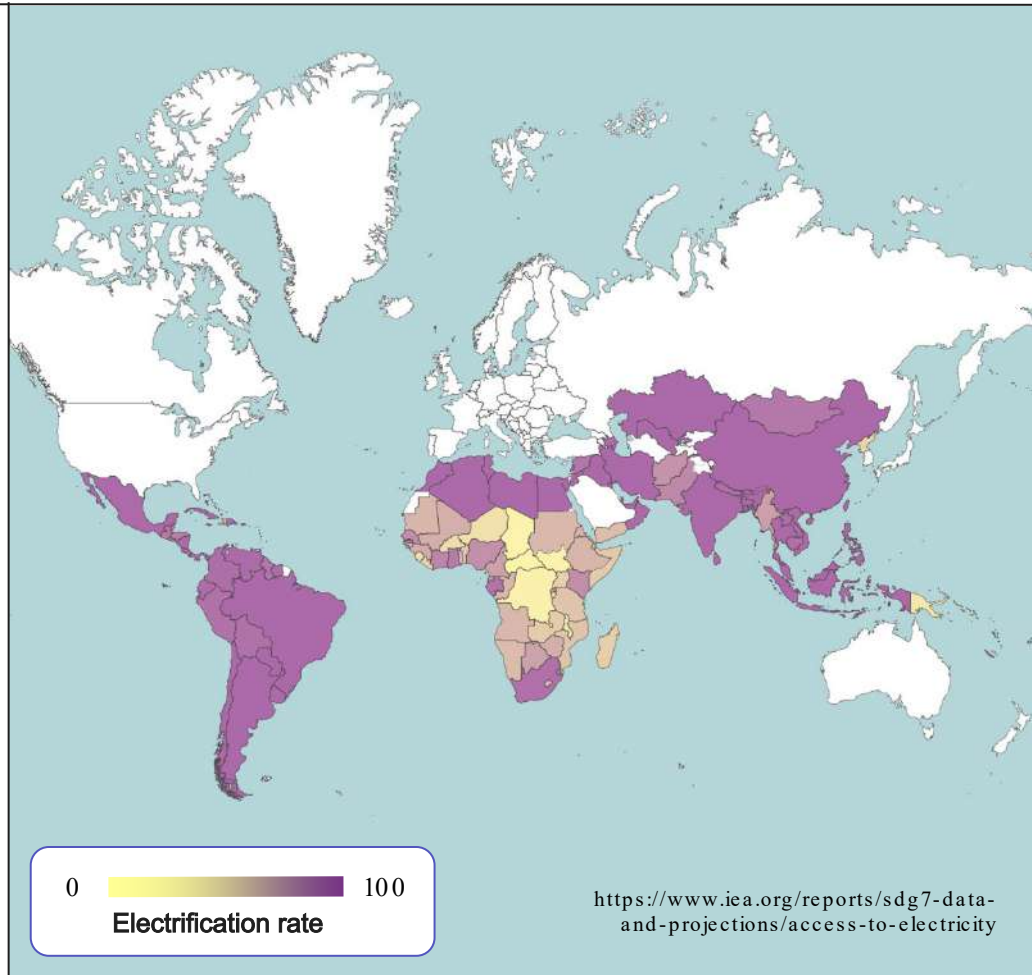
SDG7: Ensure access to affordable, reliable, sustainable and modern energy for all

Key challenges:

- Overcome energy poverty,
- Improve living standards,
- Foster economic development,
- Promote sustainability.

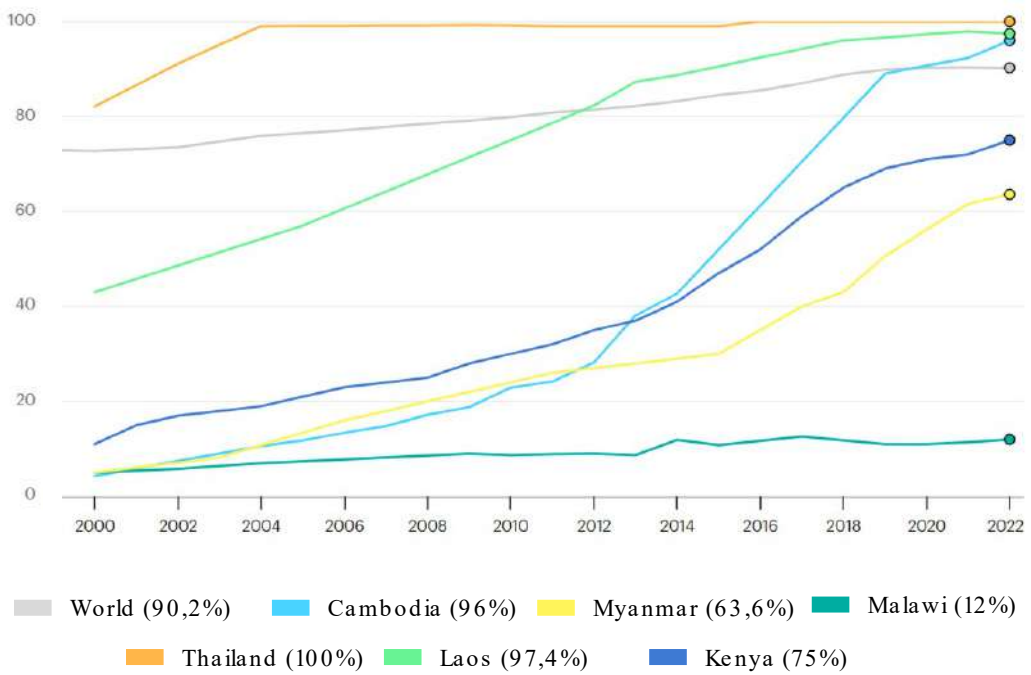
Worldwide electricity access

- 660 million people are projected to remain without access in 2030.
- Of which 85% (~560 million) in Sub-Saharan Africa.
- Developing countries in Asia are on track to achieve universal access, leaving only 70 million without access by 2030.



https://www.iea.org/reports/sdg7-data-and-projections/access-to-electricity

Share of population with access to electricity (%)



Fastest developing vs least-electrified regions

Key differences:

- Population density
- Limited infrastructure.
- Energy mix and access to modern types of energy.
- Economic development and governance.

https://www.iea.org/reports/sdg7-data-and-projections/access-to-electricity

Nighttime lights observation from space

- Remote sensing of night light emissions allows direct observation of human activity from space.
- EO-derived NTL imagery is used as proxy for quantifying and qualifying human activities:
  - Energy access and usage.
  - Population density
  - Economic activity and growth.
  - Conflict monitoring.
  - Light pollution impact on health.

The origin of Nighttime Light observations

- **1970s:** Initiation by the US Defense Meteorological Satellite Program (DMSP) - Spatial resolutions of 2.8 km to 1 km in 1992.
- **2011 and 2017:** Launch of satellites by NOAA/NASA equipped with VIIRS - DNB sensors - Monthly composites with ~500m resolution.

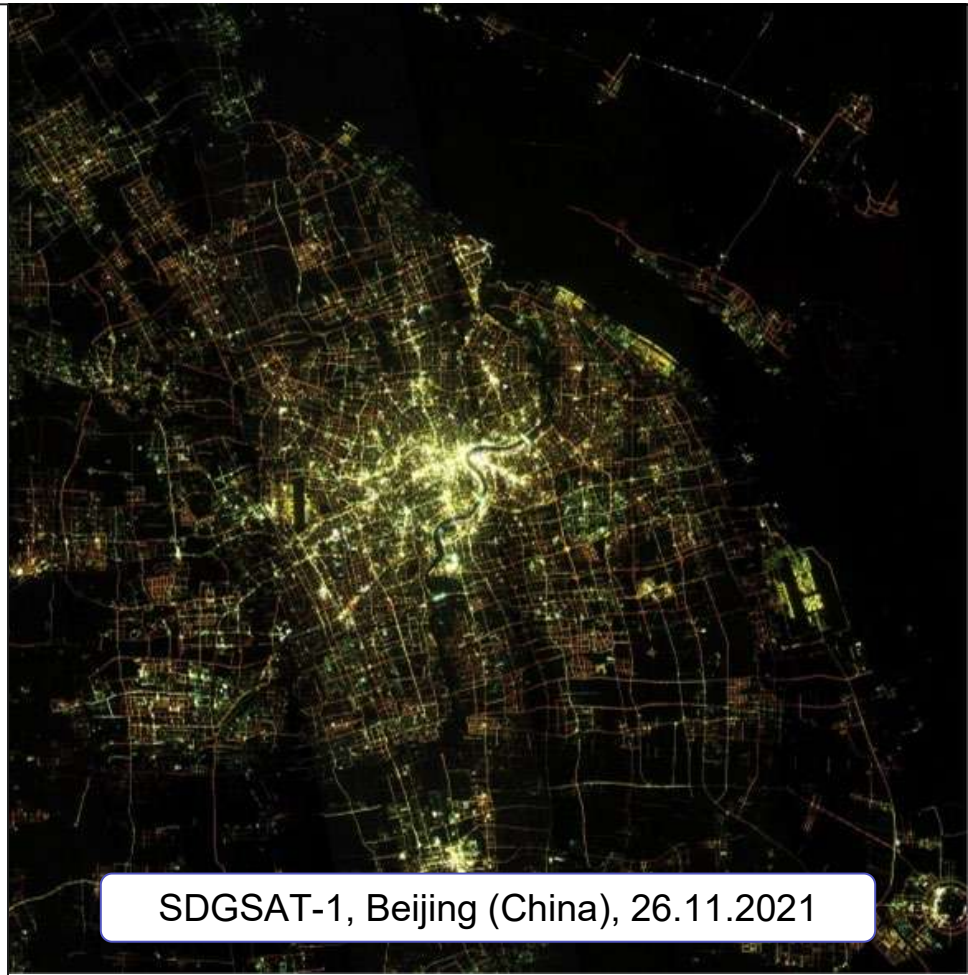
Commercial Satellites for High - to Very High- resolution NTL imagery.

- JL1-3B: 0.92 m resolution.
- EROS-B: 0.5 m resolution.

Limited scalability due to the high costs of high-resolution imagery.

Sustainable Development Goal Satellite 1 (SDGSAT-1)

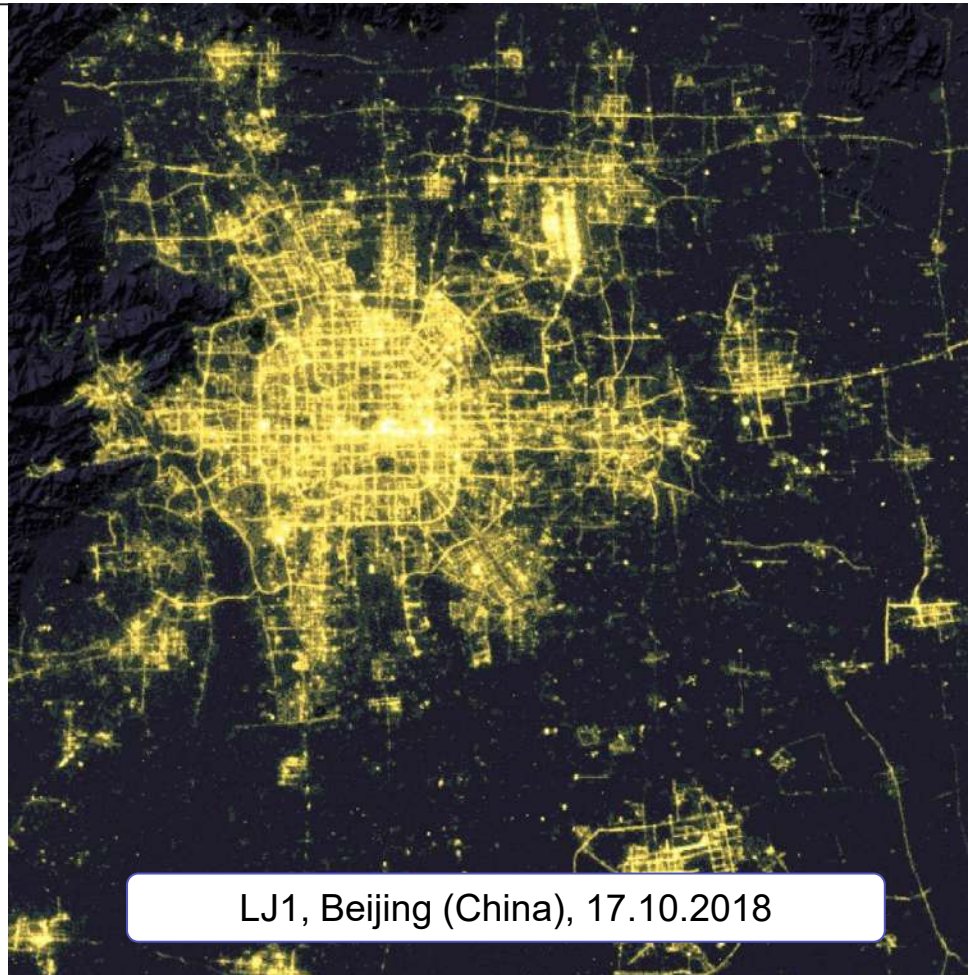
- Launched on Nov 5, 2021 as part of the Big Earth Data Science Engineering Project of the Chinese Academy of Sciences (CAS)
- Operated by the International Research Centre of Big Data for Sustainable Development Goals (CBAS)
- Equipped with *glimmer imager* for detecting NTL between 10 -40 m resolution
- Limited access quota - specific projects



SDGSAT-1, Beijing (China), 26.11.2021

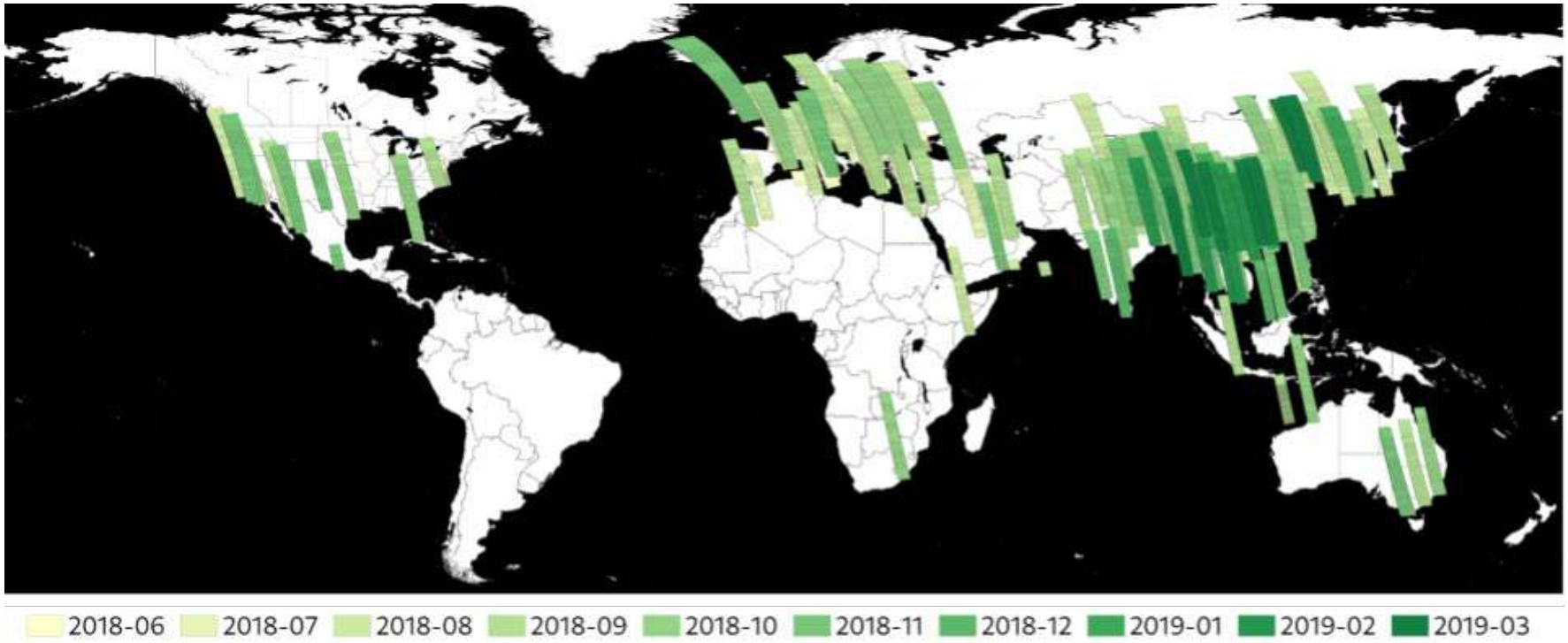
Luojia-1 (LJ1) Satellite:

- Launched on June 2, 2018, by Wuhan University (available to March 2019).
- High-resolution imaging for low-light environments (130m resolution)
- Open access scenes: 8675 250x250km scenes covering Europe, South and East Asia, North America, and Australia
- Applications in urban development monitoring, disaster response, and studying light pollution effects.

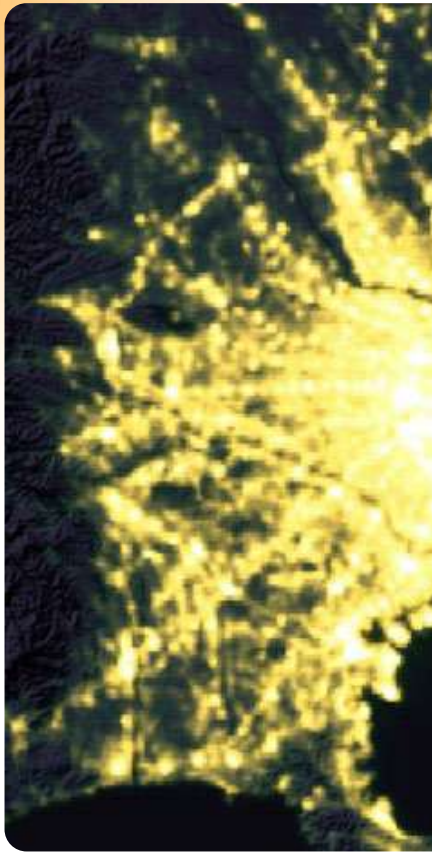


LJ1, Beijing (China), 17.10.2018

Spatial coverage of Luojia -1 (LJ1) Satellite:

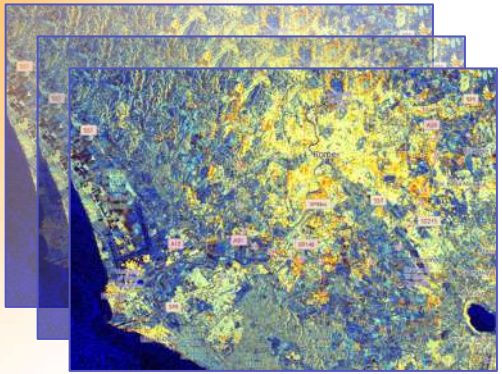


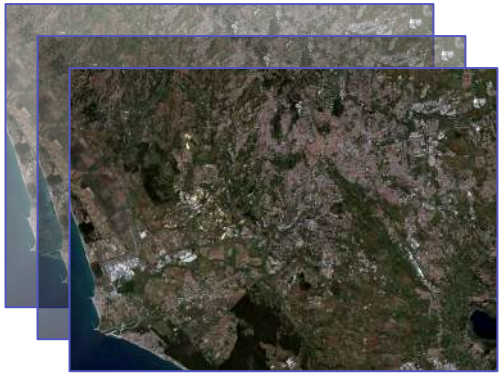
SupR-NTL: Technical objectives



- Develop a **Generative Adversarial Network (GAN)** to spatially enhance VIIRS-DNB NTL monthly composites from 500 to 130m resolution.
- Jointly exploiting **S1** and **S2** data, with **LJ1 NTL** as reference
- Create **SR-NTL monthly averages** for **multiple countries** for the last **5 years**.
- Test **SR-NTL imagery against LJ1 NTL data** not used in training to ensure robustness.

Input data





Sentinel-1 (S1) Data:

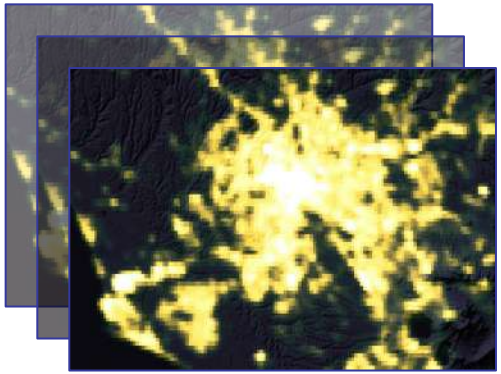
- Original Backscattering Values
- Temporal Statistics: Mean, minimum, maximum, and standard deviation values over a year.

Sentinel-2 (S2) Indicators:

- Original Bands at 10m and 20m Resolution (visible, near-infrared, and shortwave infrared bands).
- NDVI, NDBI, Modified Bare Soil Index (MBSI)
- Temporal Statistics: Mean, minimum, maximum, and standard deviation values over a year

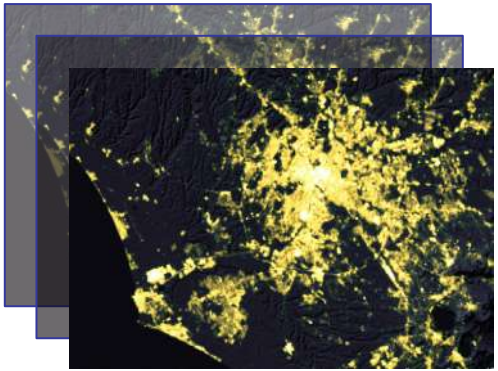
Global Sentinel-1 (S1) Coherence:

- S1 median coherence (seasonal summer dataset tested);



VIIRS-DNB NTL Data:

- Monthly and annual averages from January 2014 onwards.
- Addresses gaps due to cloud cover or solar illumination



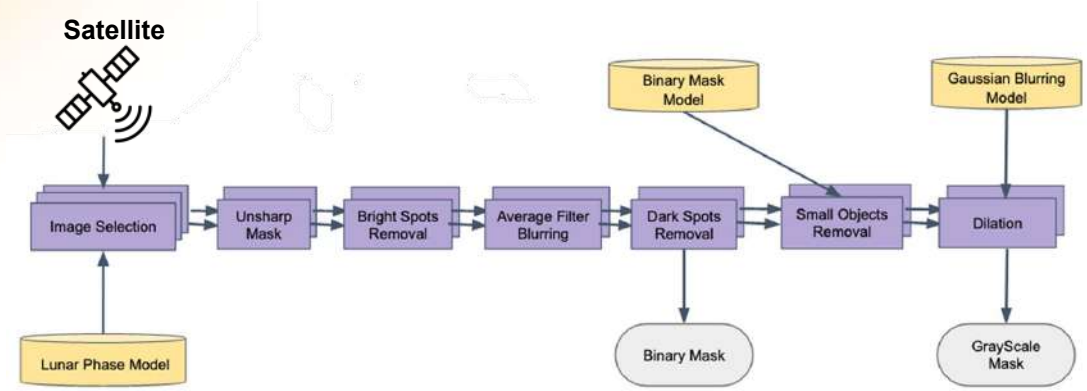
LJ1 NTL Imagery:

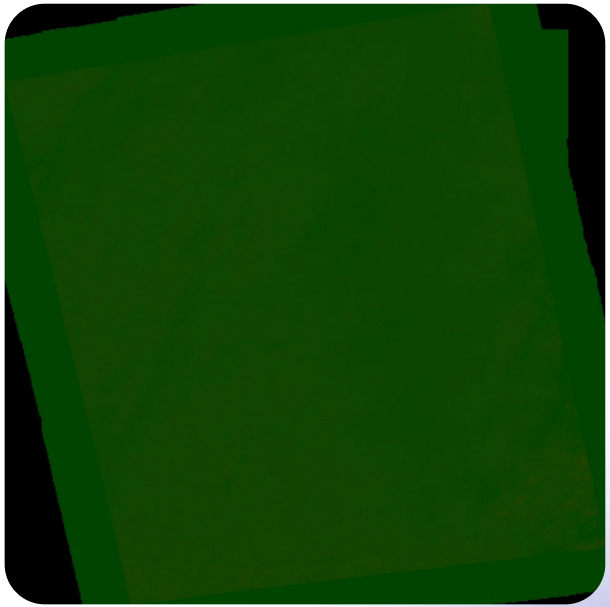
- 8675 ~250x250 km scenes between June 2018 to March 2019
- Original radiance values converted to VIIRS-DNB units.
- Cloud masking and co-registration.

https://github.com/GFZ/arosics

Preprocessing and dataset preparation

Luojia (LJ1) imagery cloud masking to reduce the scatter of stree -tlights in cloudy areas using “Luojia1-Cloud-Detection” tool

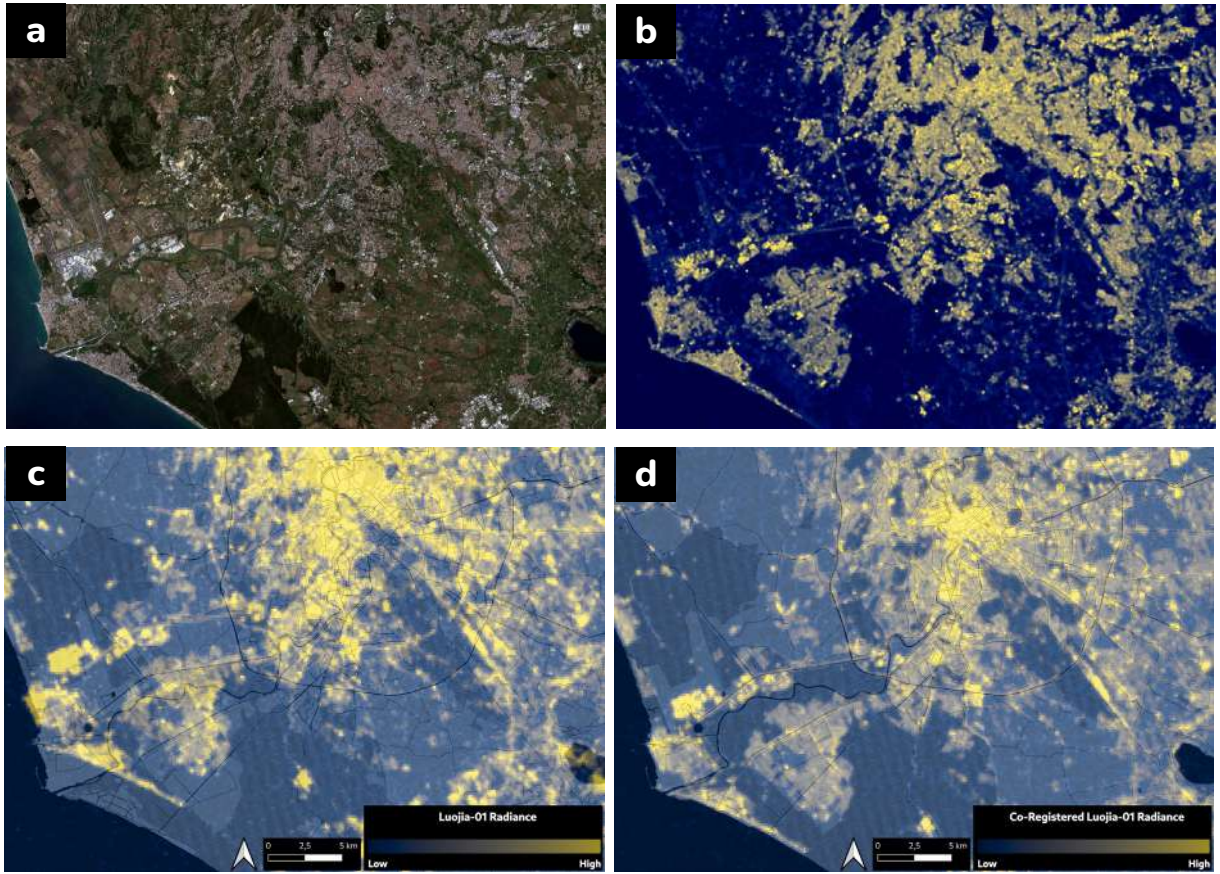




https://github.com/dedztbh/Luojia1-Cloud-Detection

Automated and Robust Open - Source Image Co - Registration Software (AROSICS)

a) Sentinel - 2 true - colour
b) Summer - day S1
c) NTL radiance from LJ1 imagery (with non - linear shift)
d) NTL radiance after geometric correction using AROSICS tool.



Envisaged System

Enhance VIIRS-DNB NTL monthly composites from 500 to 130m resolution

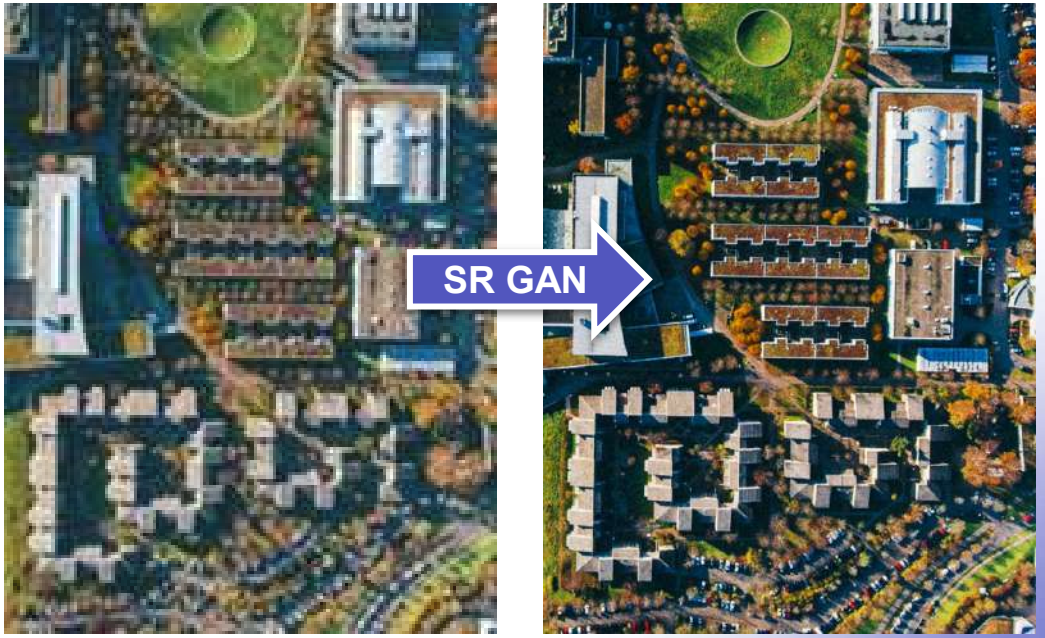
Generative Adversarial Network (GAN)

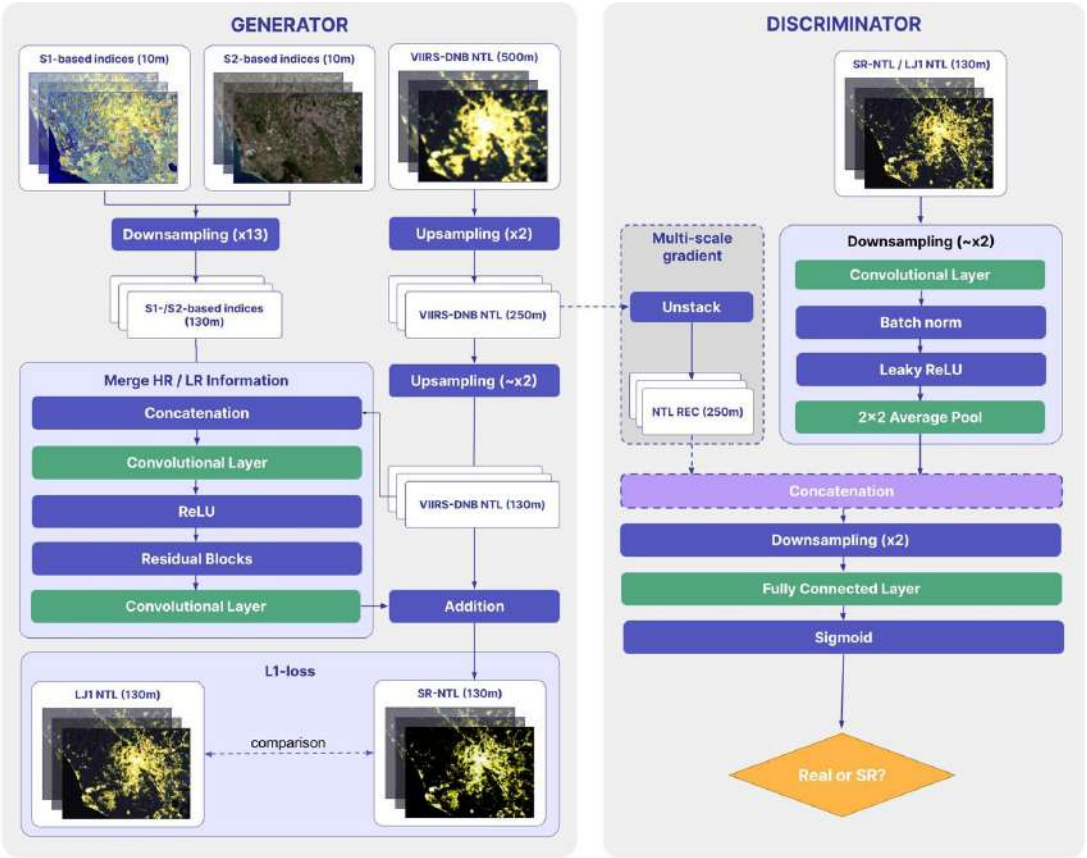
Able to learn complex relationships between high -res and low -res images with a Generator / Discriminator -based architecture that train the model in competition.

This competition enables the Generator to better learn and replicate empirical data compared to standard DNNs.

Original LR Image

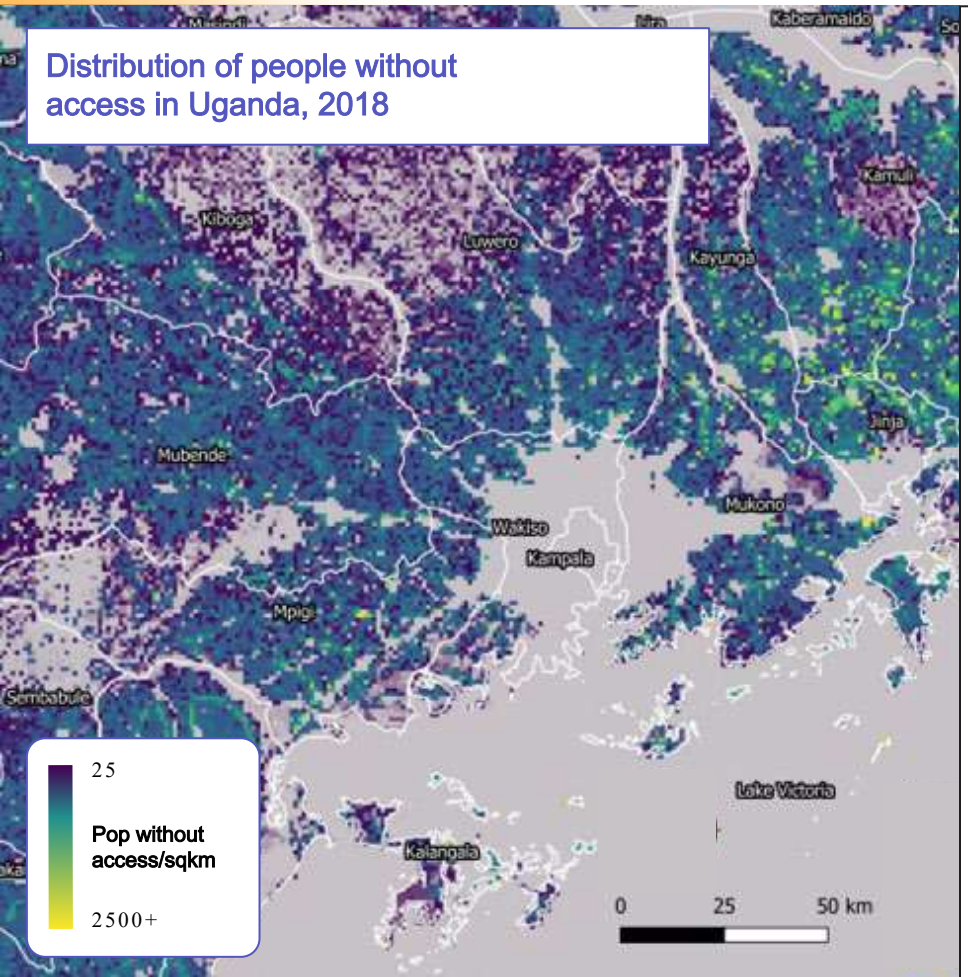
4 x HR image





- Train GAN model using S1/S2 indices and VIIRS-DNB data.
- Downsample S1/S2 (130m).
- Upsample VIIRS-DNB (130m).
- **Generator:** Uses residual blocks for high-resolution details.
- **Discriminator:** Differentiates real vs. generated images.
- Multi-scale gradient to improve stability and convergence
- Use MAE, PSNR, SSIM for quality check.

Use Case: Generation of electricity access maps



International Institute for Applied Systems Analysis (IIASA)

- Classification of urban and rural areas using WSF-pop layer (DLR).
- Calculation of the median SR-NTL radiance per grid cell
- Grid-cell categorization (lit or dark)
- Population matching with lit/dark per grid cell
- Estimation of energy consumption

Results comparison using VIIRS-DNB original imagery and generated SR-NTL imagery (500m vs 130m resolution).

Falchetta, G., et al. (2019): A high-resolution gridded dataset to assess electrification in sub-Saharan Africa. Scientific Data.

Demonstration sites

SR-NTL monthly averages maps will be produced for the last 5 years for selected countries in South-East Asia and Sub-Saharan Africa.

Any questions?

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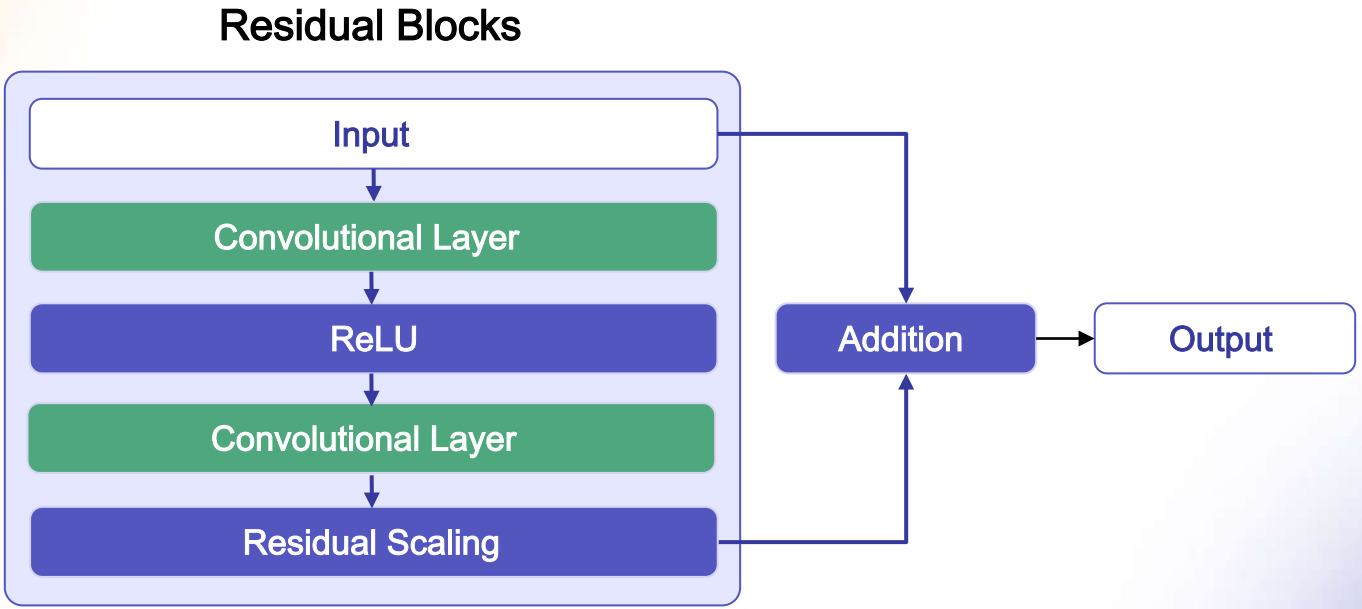
Residual blocks workflow



Electricity access maps workflow