SUREDOS24

Super-Resolution and Downscaling for EO and Earth Science

A Methodology Based on AI Modules for Super-Resolution of Sentinel-5P Level 1B Data and Sentinel-3 Level 2 LST Data

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30 May 2024 | ESA-ESRIN | Frascati (Rome), Italy

Outline

- Motivation and Scope
- Use Case 1: Sentinel-5p and PRISMA L1 data
  - Methodology
  - Preliminary results
- Use Case 2: Sentinel-3 and Landsat L2 LST data
  - Methodology
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- Take home messages and next steps

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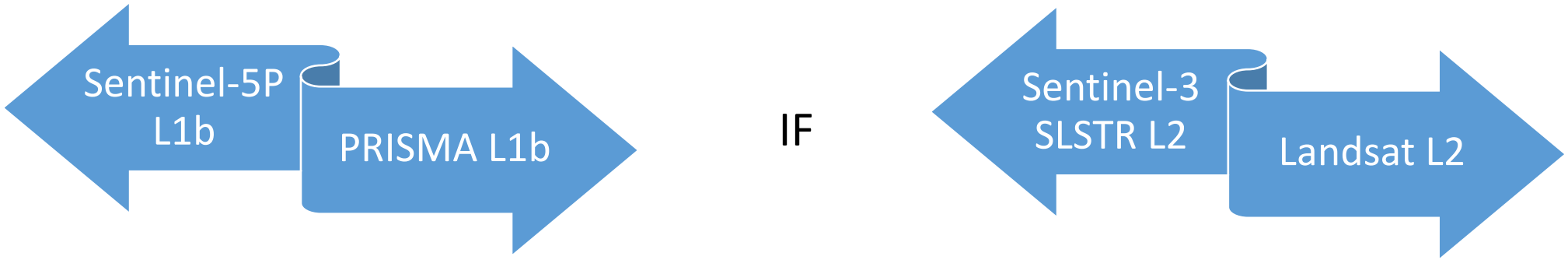
Motivation

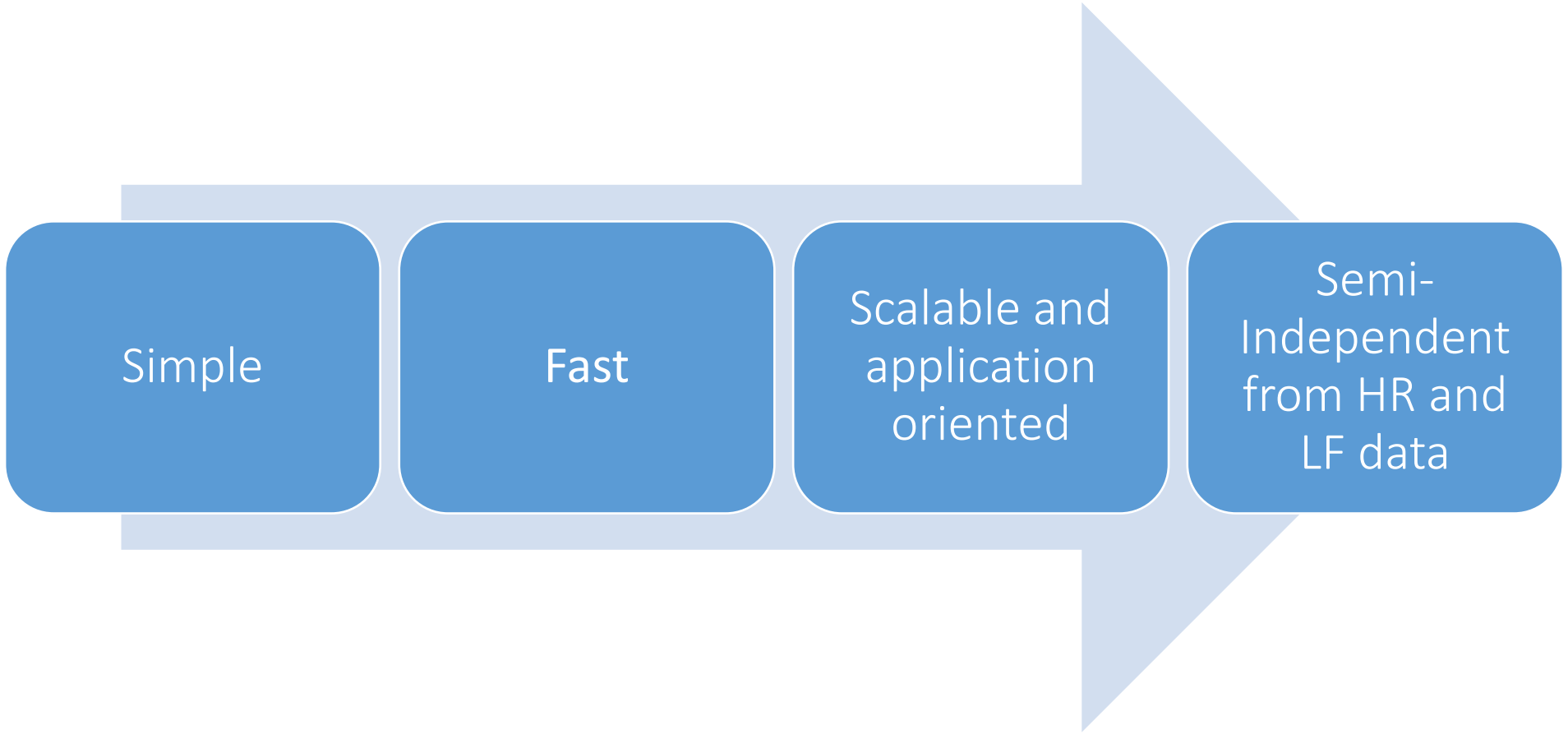
Topic: Super Resolution of HF (high frequency) and LR (low resolution) data to generate "corresponding" LF (low frequency) and HR (high resolution) data



- Scarce literature (very limited number of publications)
- Lack of dataset
- Mostly with simulated data
- Constrains in the replicability/scalability (e.g. dependence of LF and HR data in input)

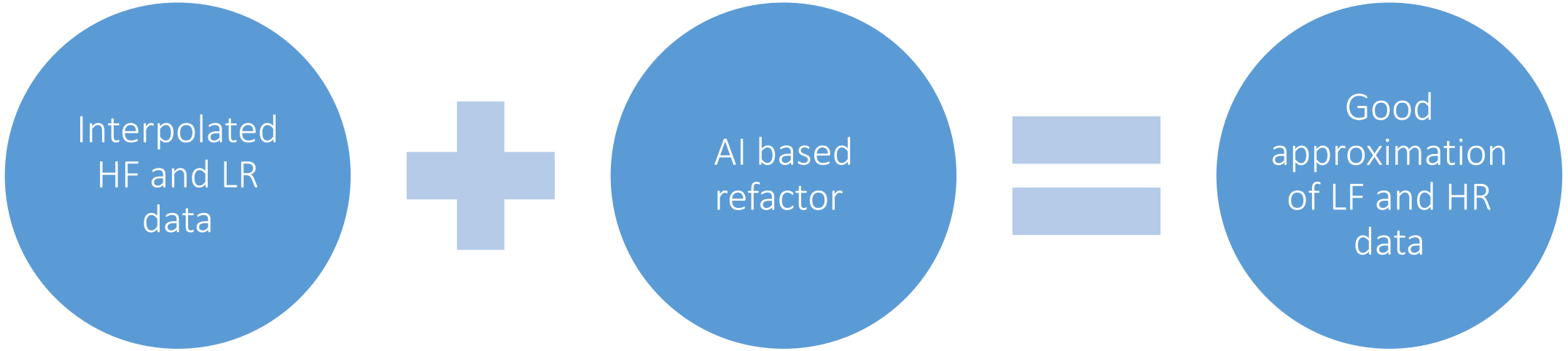
Scope

Design and first evaluation of a methodology for Super Resolution of HF (high frequency) and LR (low resolution) data to generate corresponding LF (low frequency) and HR (high resolution) data



Scope

General Idea



Sentinel-5P L1b

Sentinel-3 SLSTR L2

Shallow Neural Network

PRISMA L1b

Landsat L2

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Sentinel-5P and PRISMA Mission Overview

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PRISMA product:

240 Bands covering the VNIR and SWIR spectral regions

(400 – 2500 nm)

Spatial res: 30 m

Parameter	VNIR channel	SWIR channel	Pan channel
Spectral range	400-1010 nm	920-2505 nm	400-700 nm
Spectral resolution (FWHM)	≤ 12 nm	≤ 12 nm	-
Spectral bands	66	171	1
Swath width	30 km (FOV = 2.77°)		
Spatial resolution	30 m		5 m

TROPOMI product:

Band 8

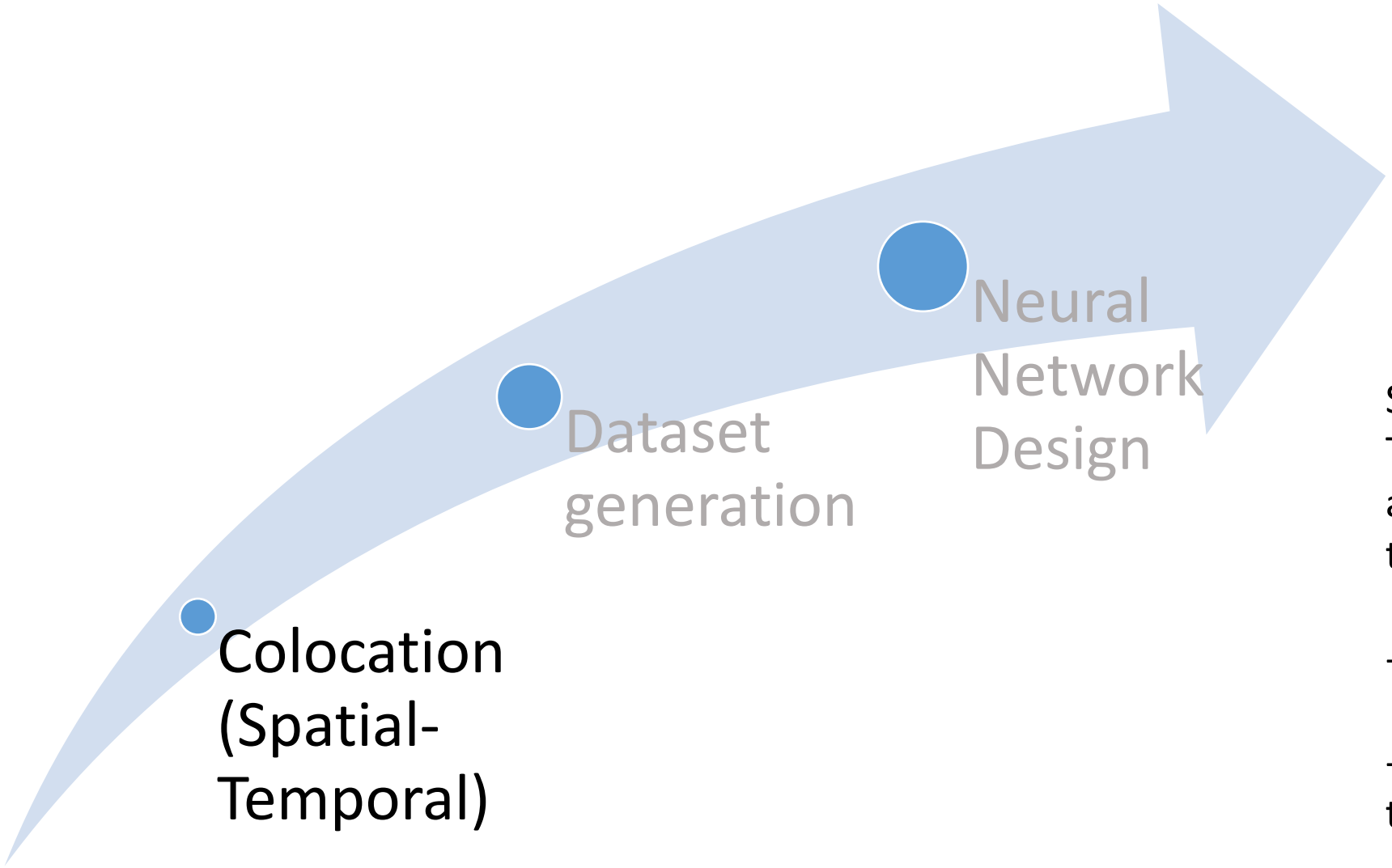
480 spectral channels

(2343 – 2389 nm)

Spatial res: 5.5 x 7 km (since August 2019)

Spectral ranges	Number of channels	Spectral resolution
270-495 nm	1200	0.55 nm
710-775 nm	600	0.55 nm
2305-2385 nm	800	0.25 nm

Methodology - Colocation



Selection of PRISMA L1 and TROPOMI L1B (Band 8) data according to spatial and temporal criteria:

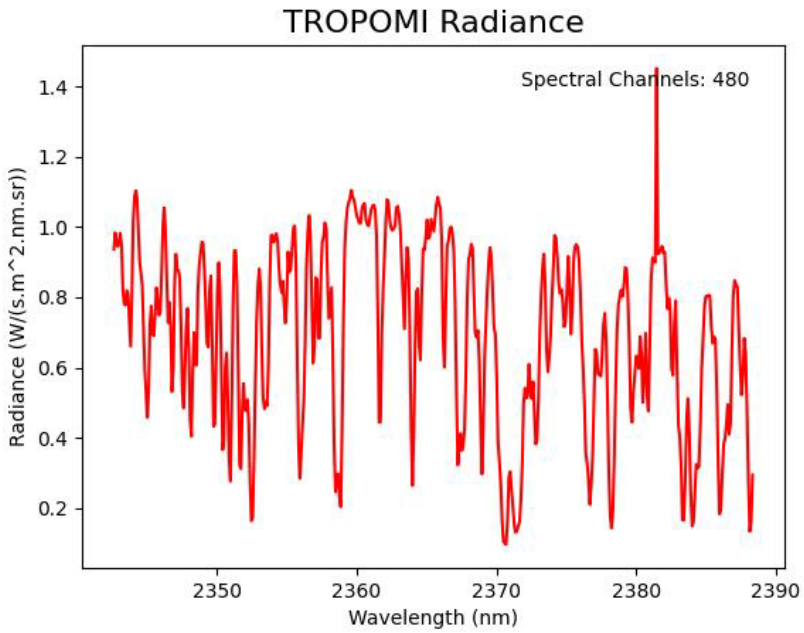
- Spatial overlap of acquisitions

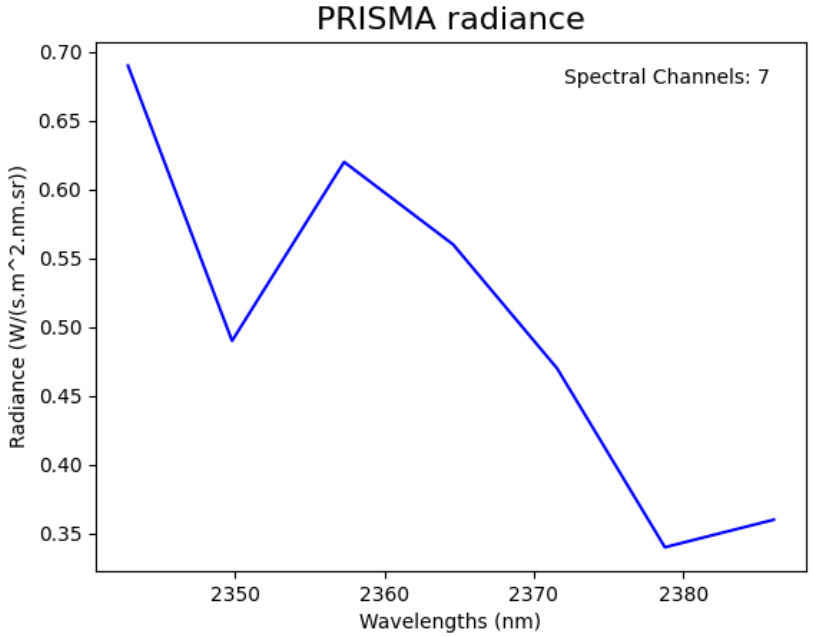
- Acquisition with a maximum time interval of one hour

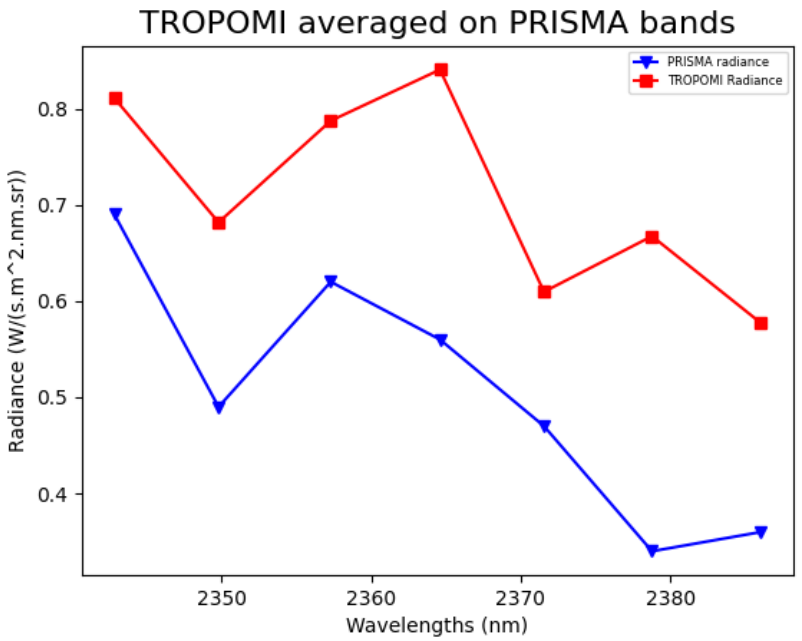
PRISMA and TROPOMI colocation

	Acquisition day and time
PRISMA	2023-03-22 10:30:37
TROPOMI	2023-03-22 10:41:10

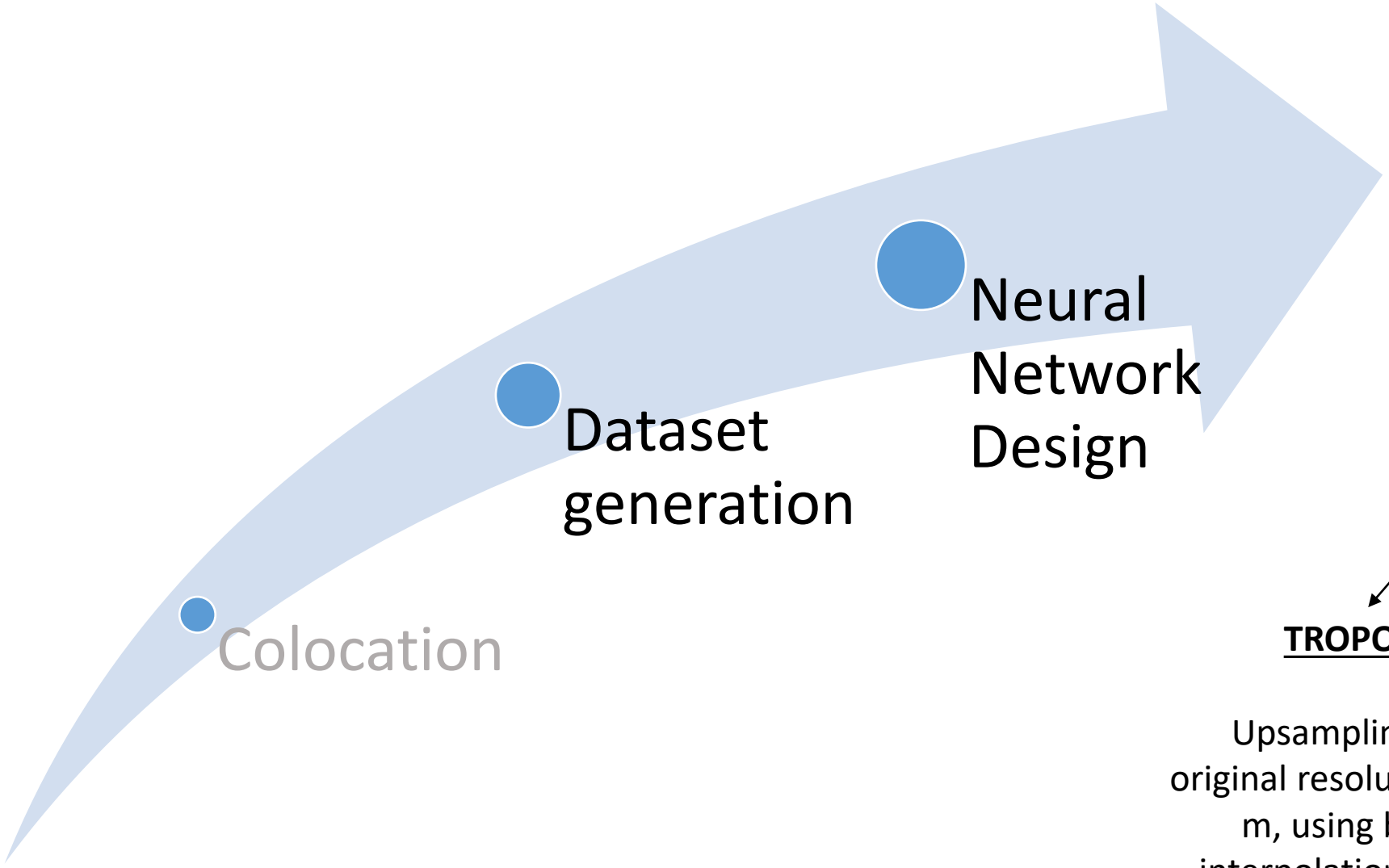
Site: Milano







Methodology – Dataset generation



Dataset generation

TROPOMI:

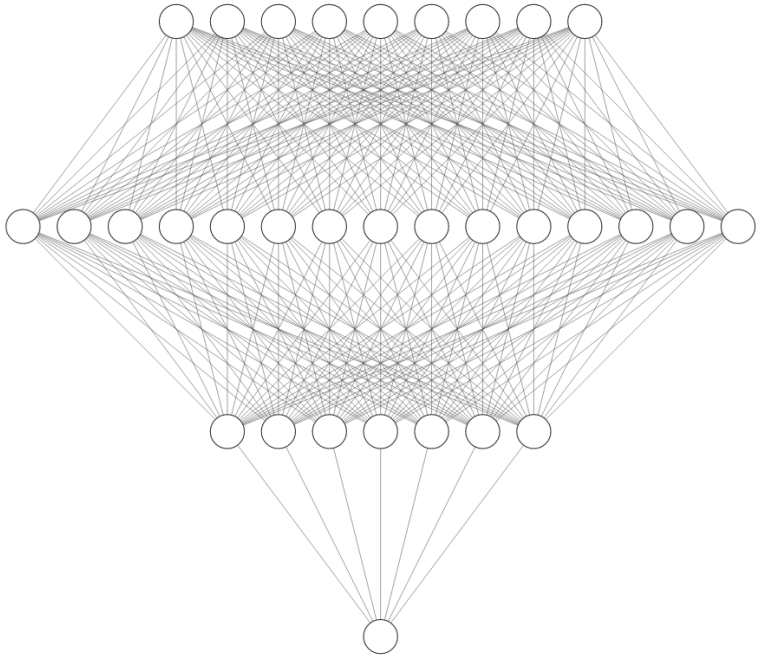
Upsampling, from original resolution to 300 m, using bicubic interpolation method

PRISMA:

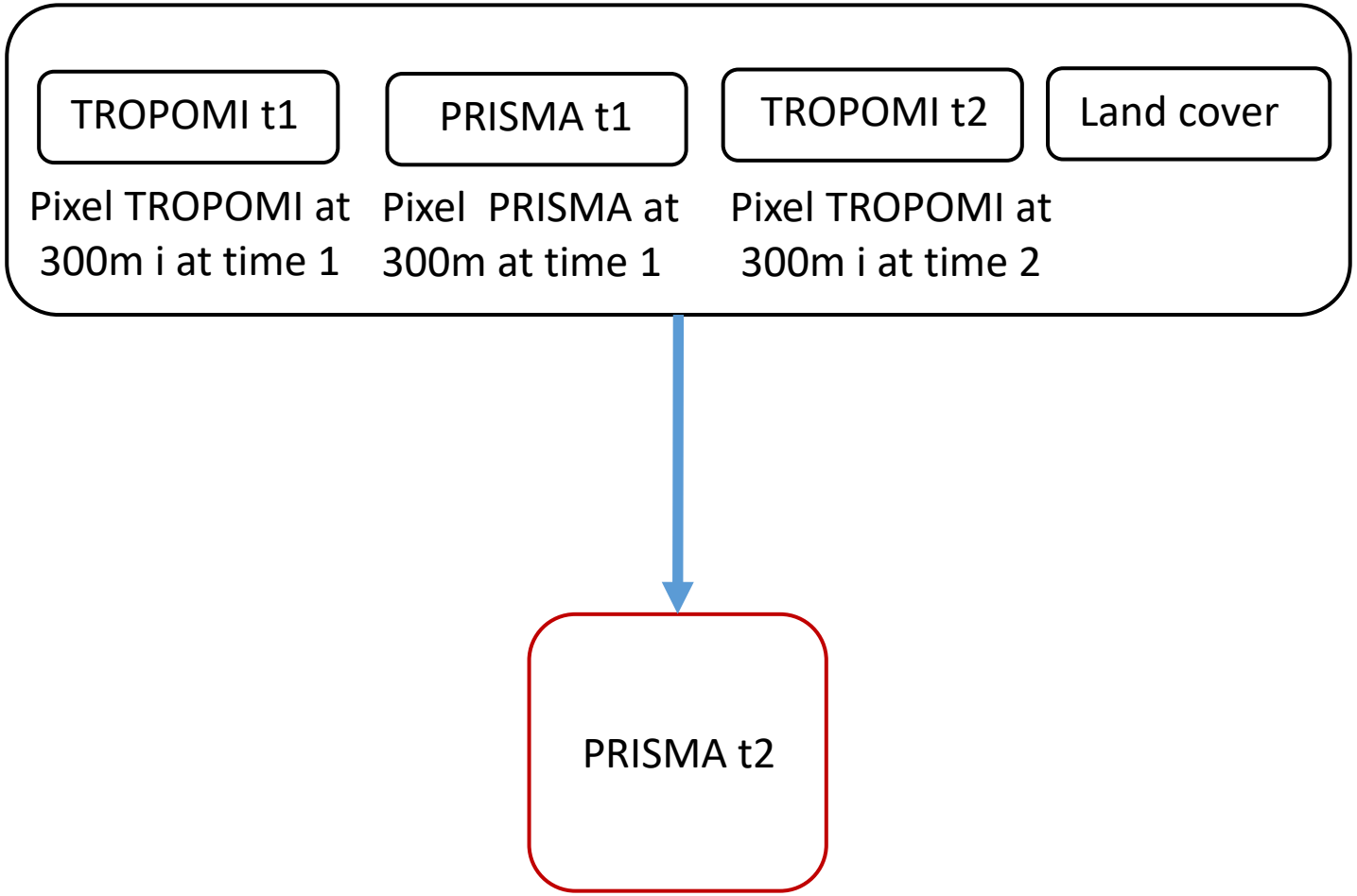
Downsampling, from original resolution to 300 m, using average interpolation method

Neural Network Design

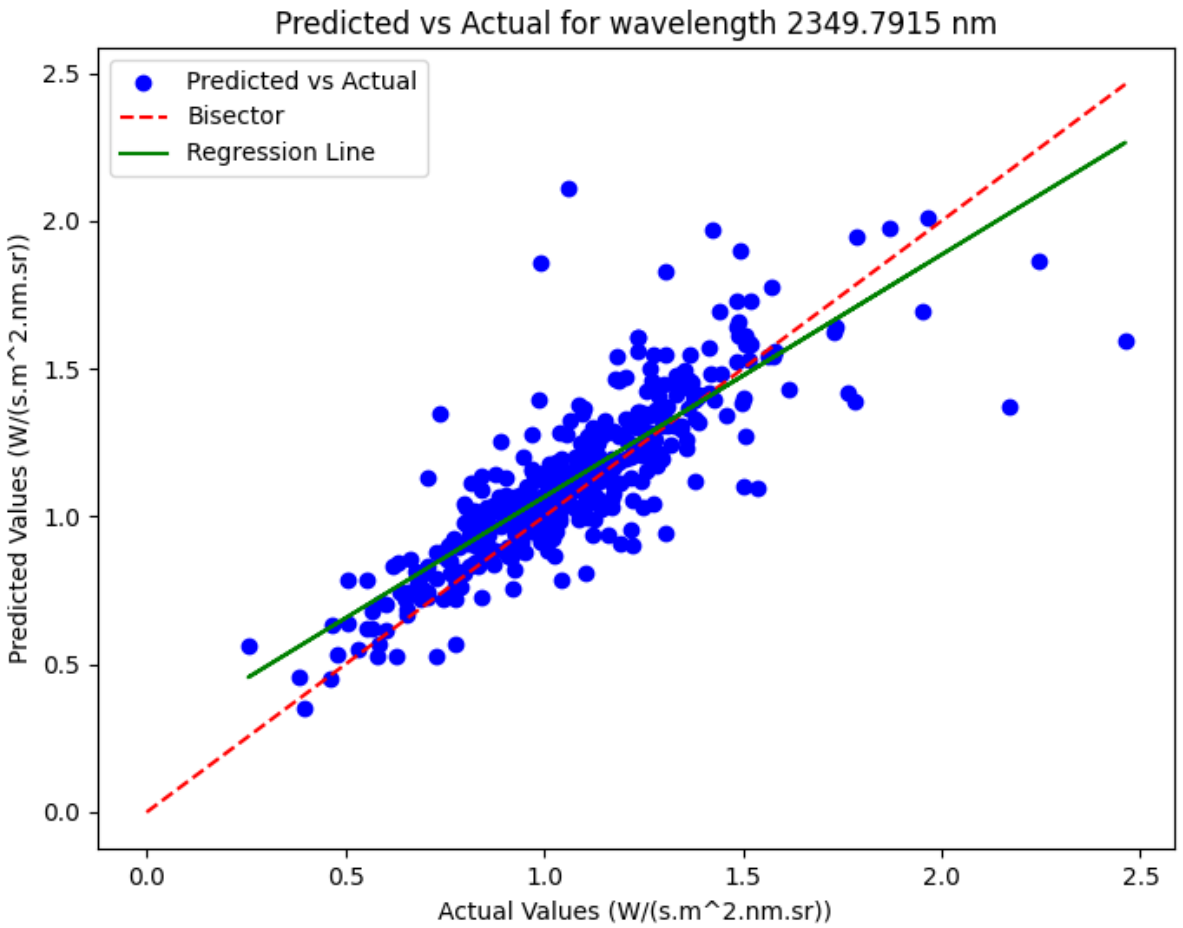
INPUT:

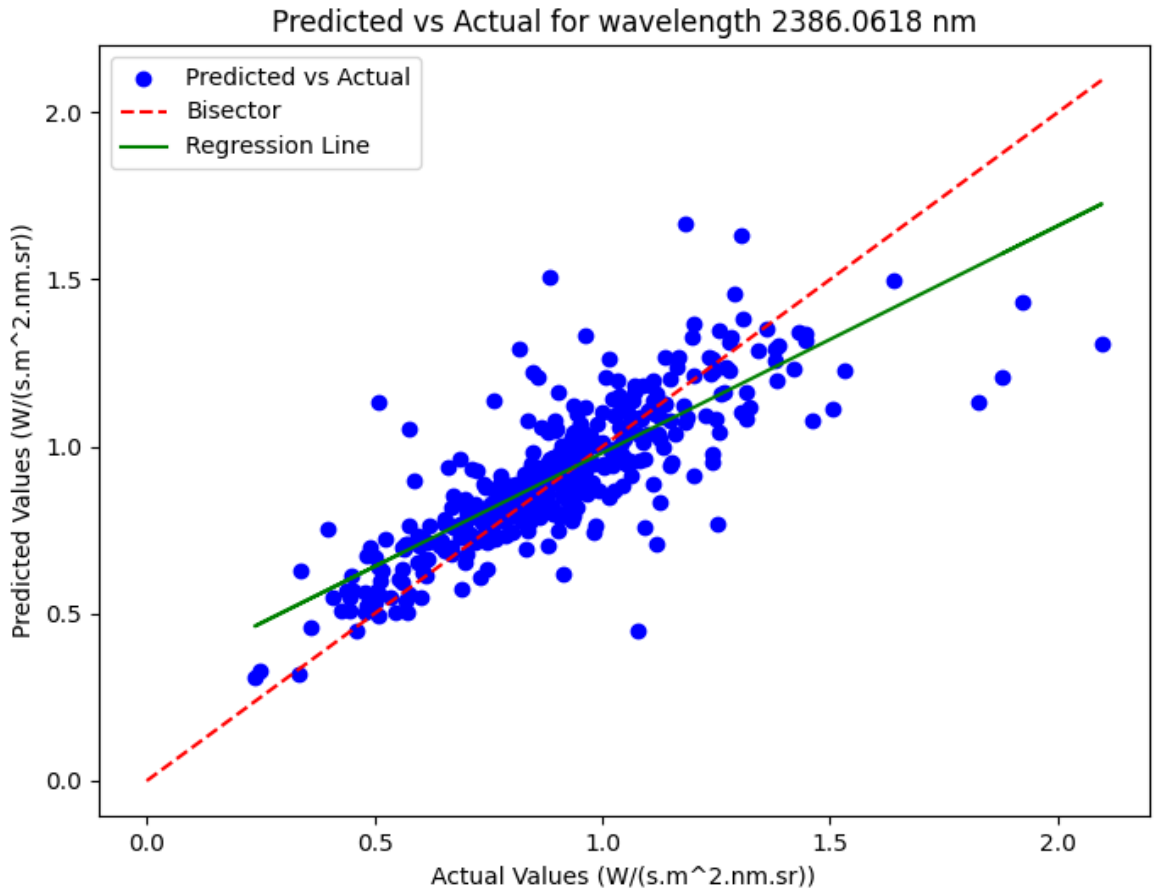


OUTPUT:



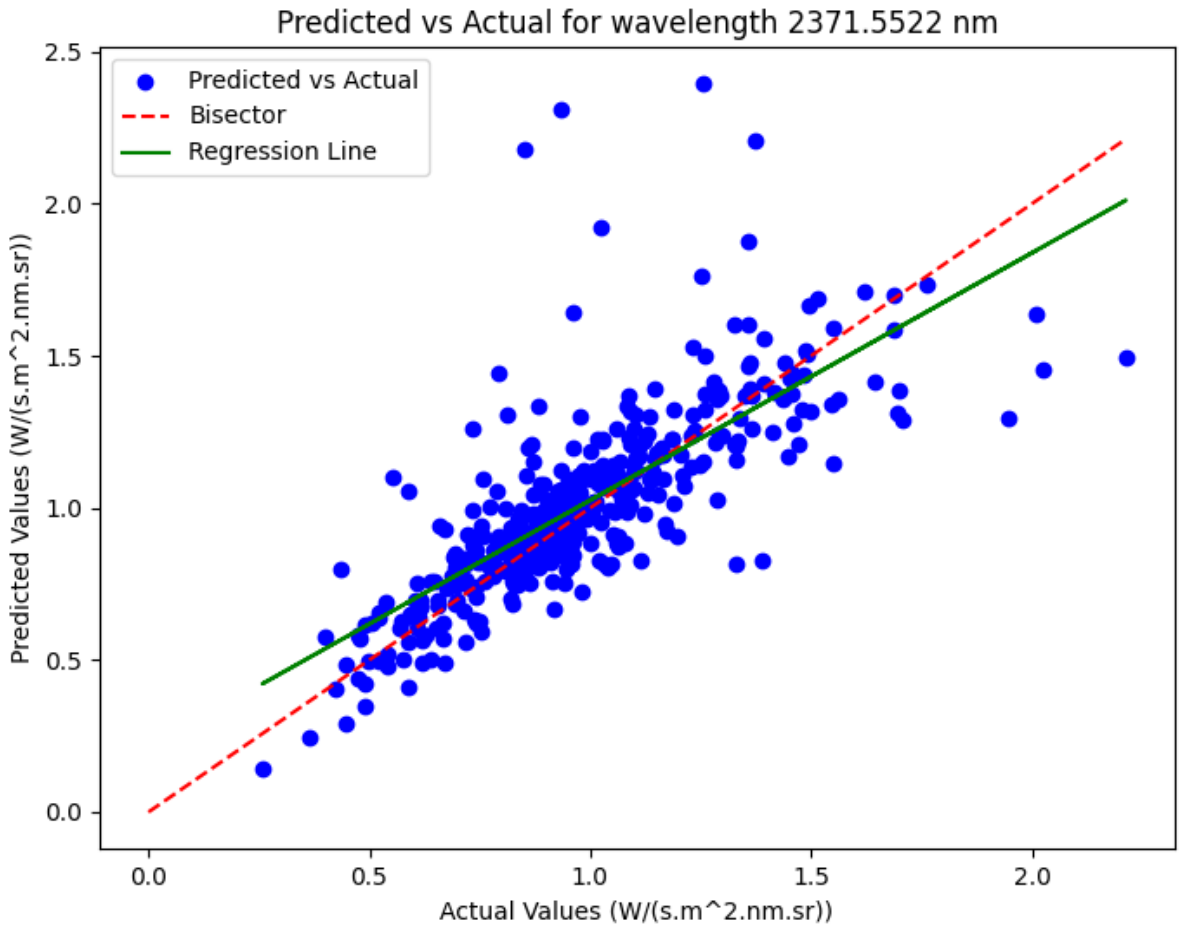
Preliminary results

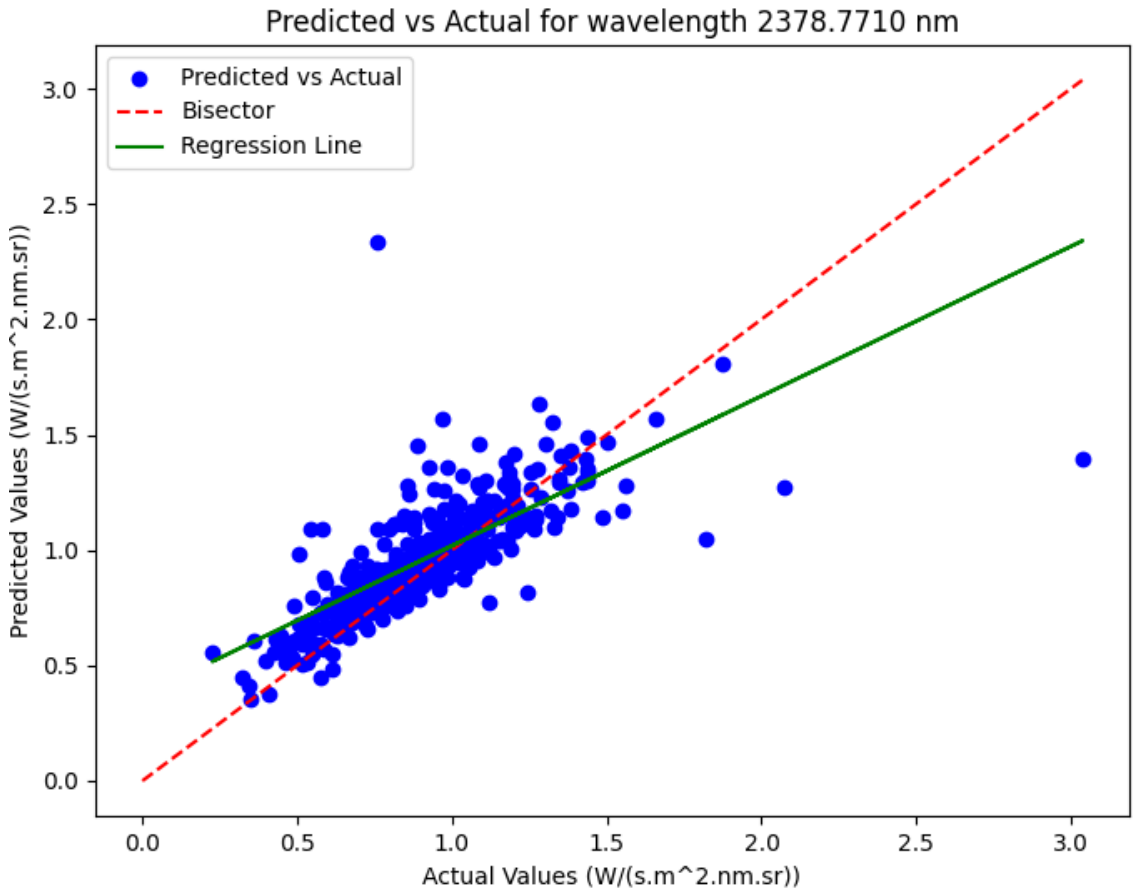




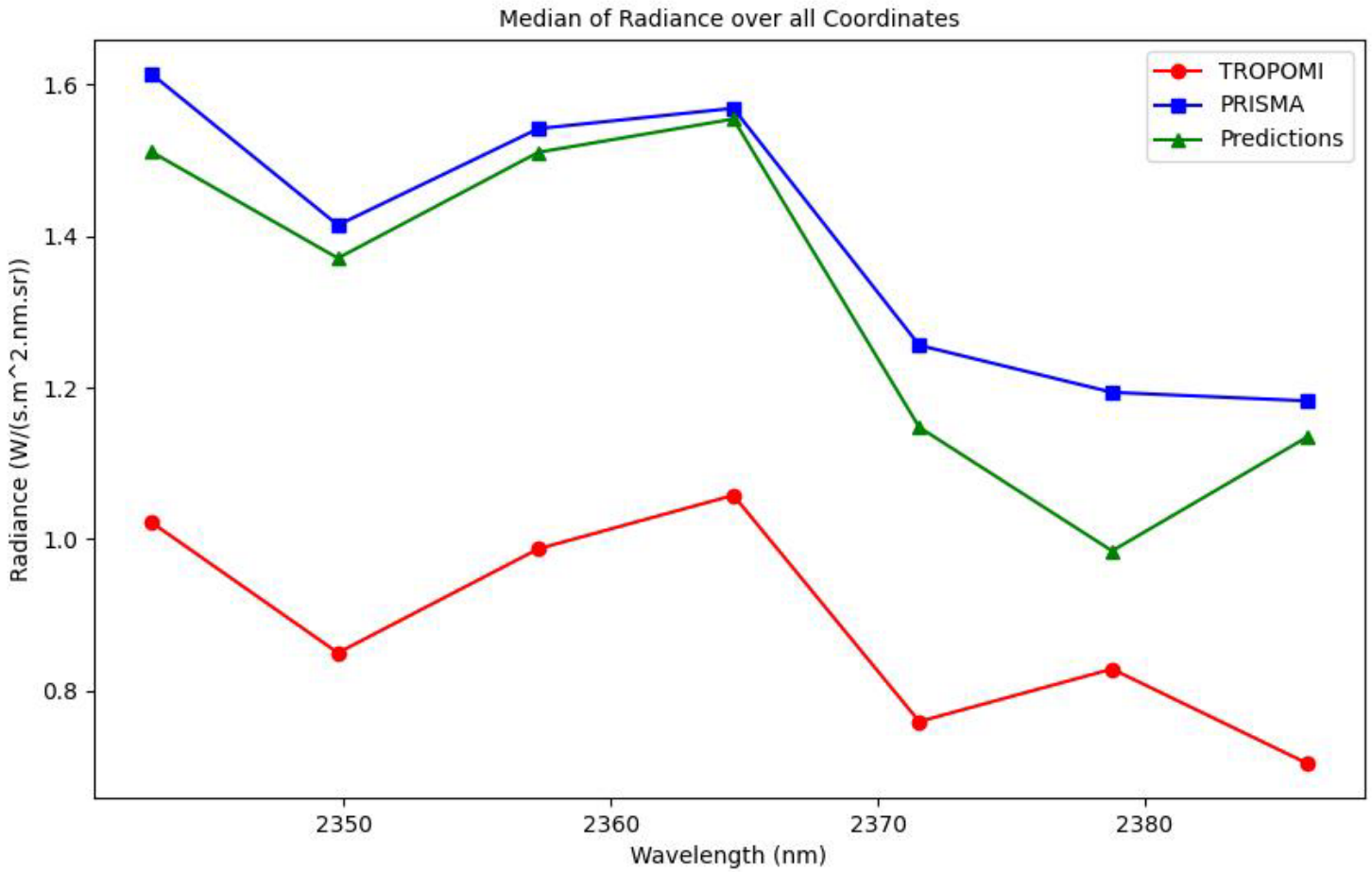
Max CH_4 absorbance for retrieval (with PRISMA data): 2349.7915 nm

Preliminary results





Preliminary results PRISMA in Sentinel-5P Band8



	RMSE	Relative RMSE
Band 1 (2342.8228 nm)	0.270	0.211
Band 2 (2349.7915 nm)	0.184	0.166
Band 3 (2357.2937 nm)	0.241	0.190
Band 4 (2364.5945 nm)	0.301	0.245
Band 5 (2371.5522 nm)	0.200	0.201
Band 6 (2378.771 nm)	0.207	0.225
Band 7 (2386.0618 nm)	0.175	0.187

Performances over urban areas seem more accurate than over vegetated areas

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Sentinel-3 and Landsat Overview

Sentinel-3 instruments:

- OLCI (Ocean and Land Colour Instrument);
- STM (Altimetry Surface Topography Missi on);
- **SLSTR** (Sea and Land Surface Temperature Radiometer)- provide a reference **Land and Sea Surface Temperature** dataset.

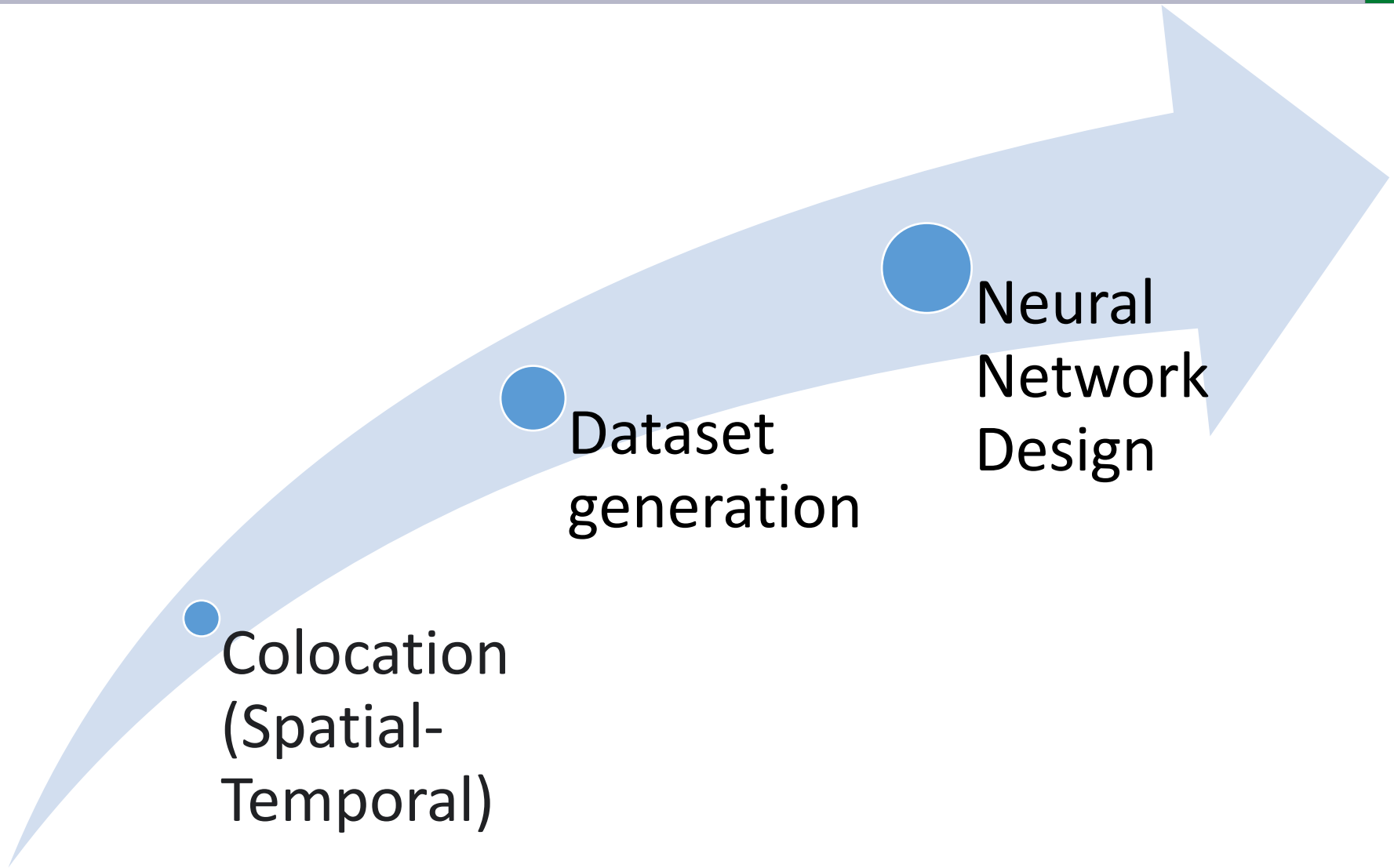
  - Swath: 1400 km
  - Revisit time:daily
  - Spatial resolution: **1 km**

Landsat 8/9 instruments:

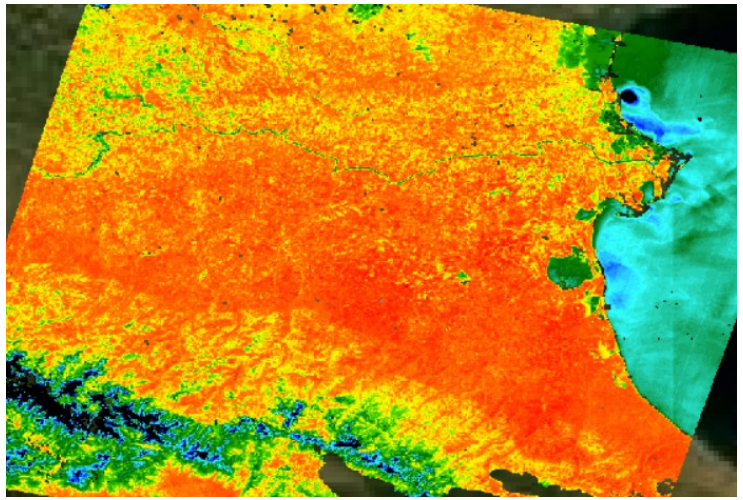
- OLI (Operational Land Imager)- visible, near-infrared, shortwave-infrared bands;
- **TIRS** (Thermal Infrared Sensor) - thermal infrared radiation.

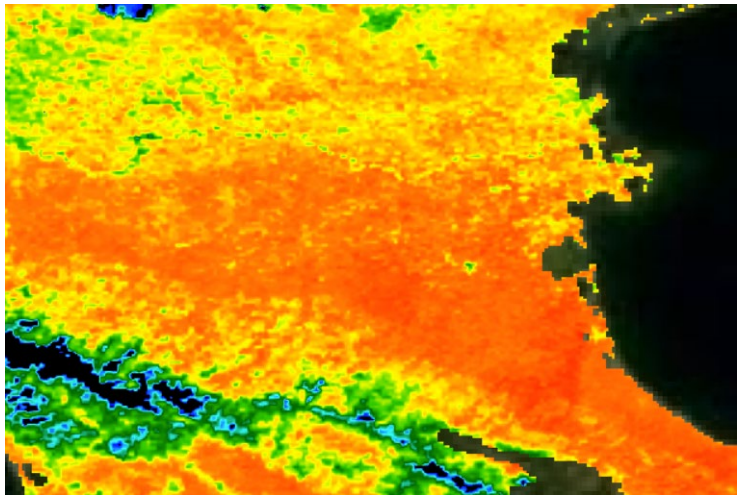
  - Swath: 185 km
  - Revisit time:together, Landsat 8 and Landsat 9 provide 8-day coverage.
  - Spatial resolution: **30m** (the thermal bands are re-sampled from 100 m)

Methodology



Methodology- Dataset generation





Site: Emilia-Romagna, Italy

LST data in different locations and seasons

- Capture temperature seasonality throughout the year;
- Maximum time difference of **one hour** between the two data.

Preprocessing:

LANDSAT L2:

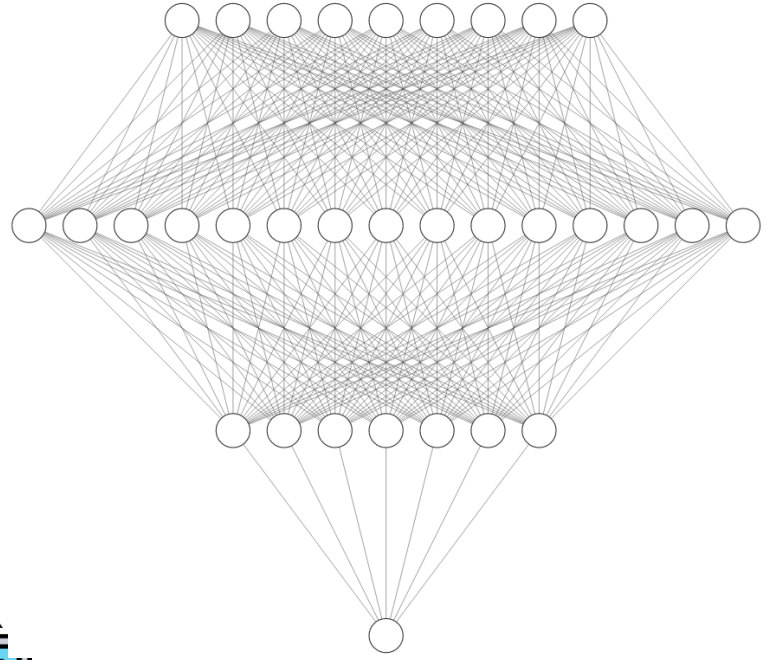
- Cloud mask application and derive LST filtered pixels;
- Resampling from 30 to 300 m;

SENTINEL-3 L2:

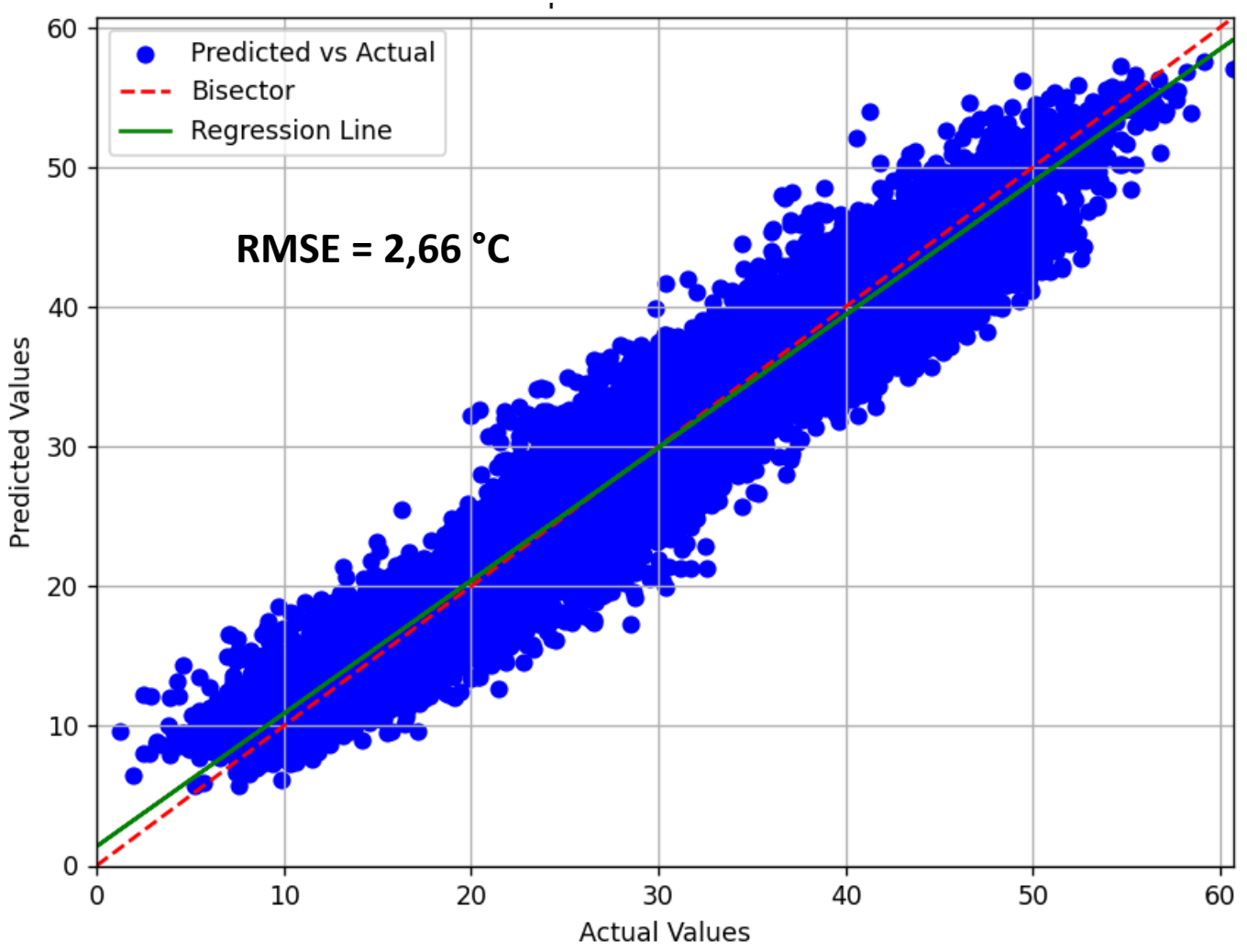
- Cloud mask application and derive LST pixels;
- Upsampling to the same spatial resolution of Landsat resampled data (300m with bilinear interpolation)

Methodology- Neural Network Design

INPUT: Geospatial informations and Sentinel-3 LST upsampled.



OUTPUT: Landsat LST resampled.



Results- Scatterplot in urban area

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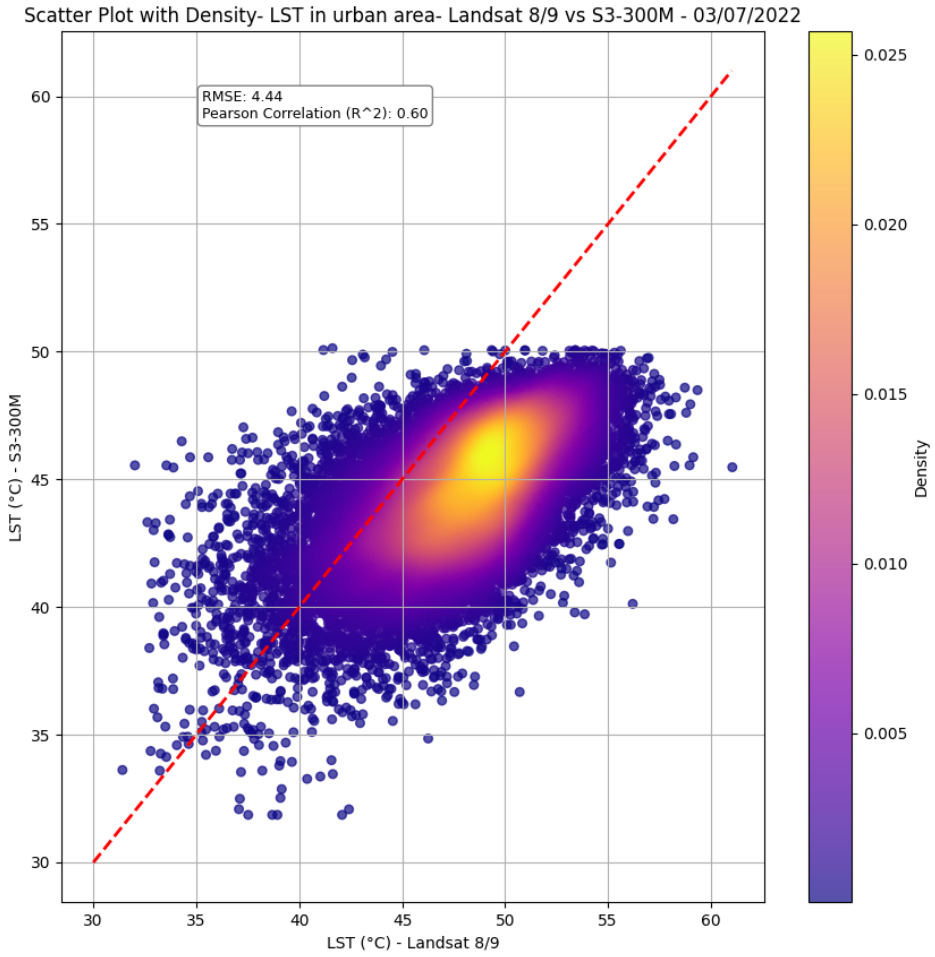
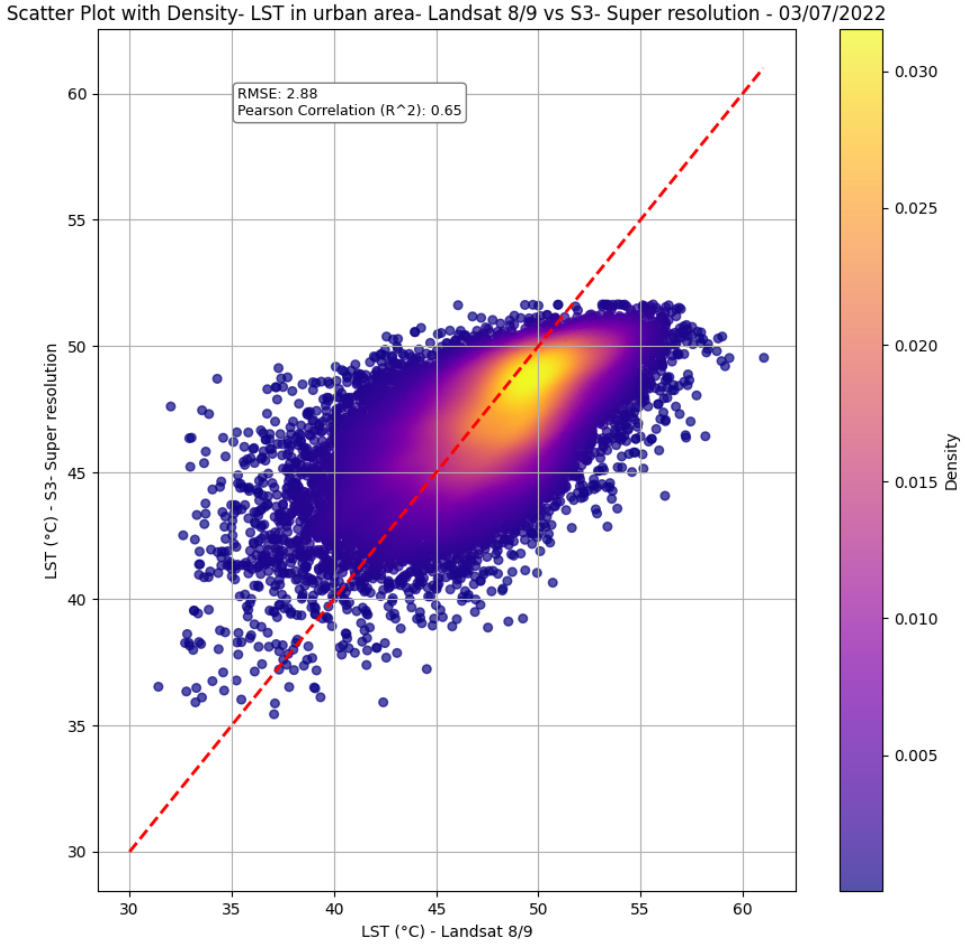
Landsat 8/9 resampled vs S3 upsampled

RMSE = 4.44 °C



Landsat 8/9 resampled vs SR

RMSE = 2.88 °C



Results- Scatterplot in vegetation area

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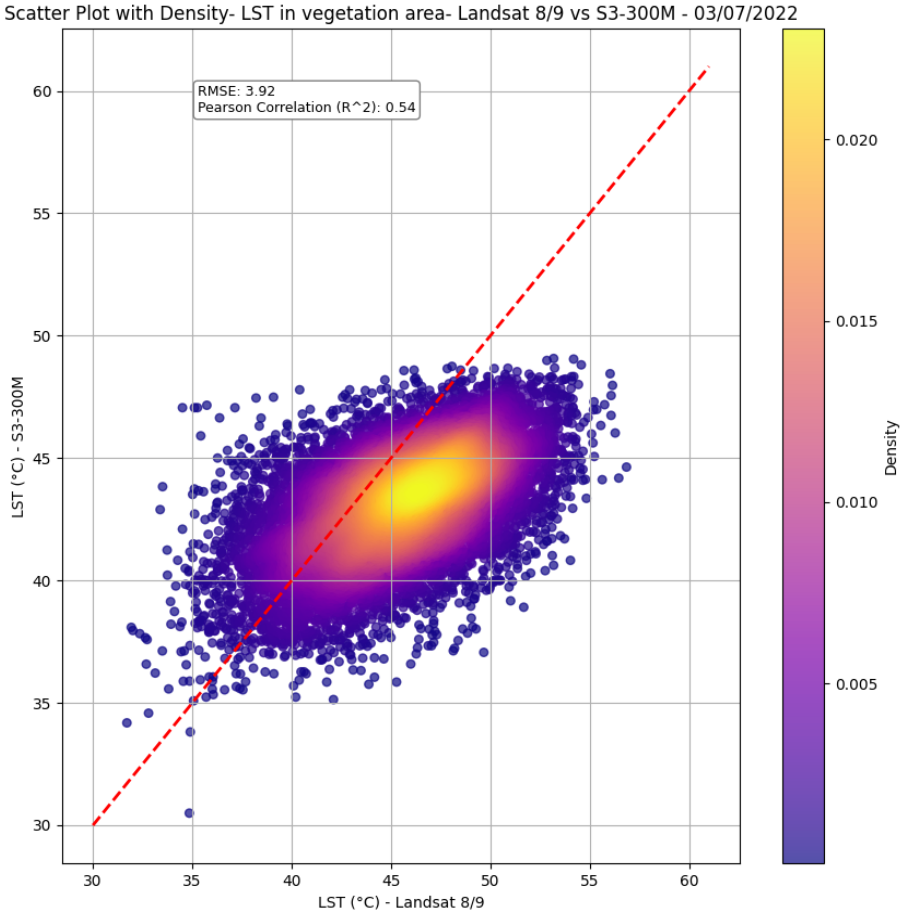
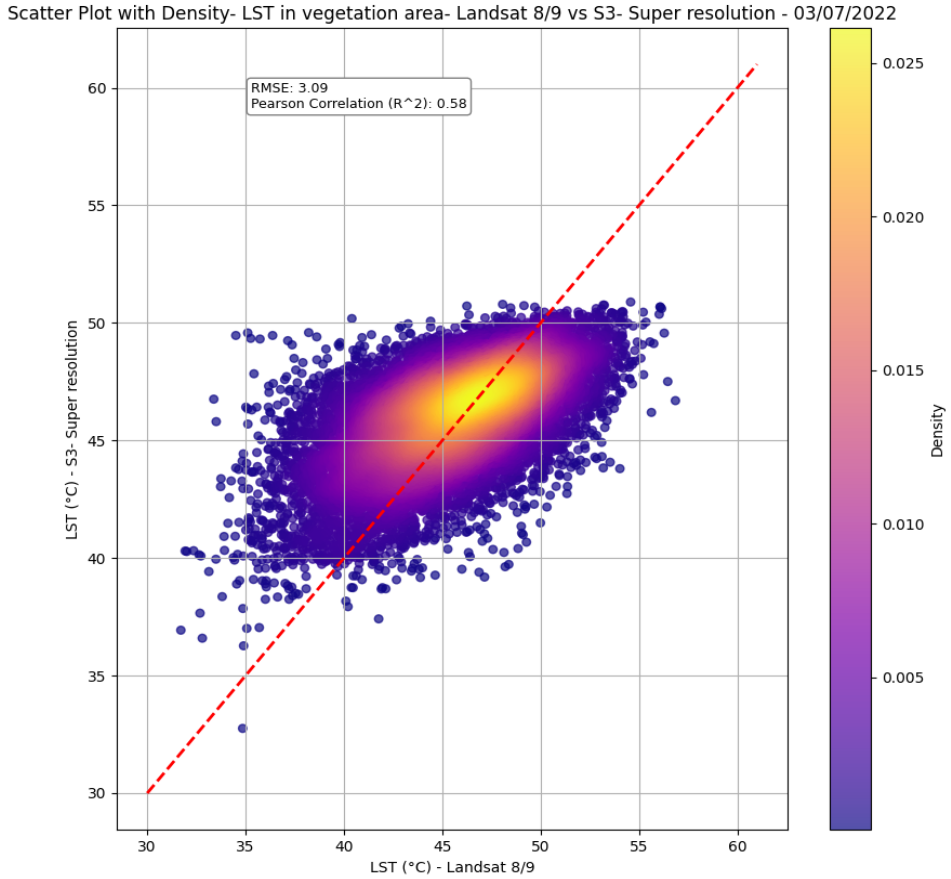
Landsat 8/9 resampled vs S3 upsampled

RMSE = 3,92



Landsat 8/9 vs SR

RMSE = 3,09



Results

BOLOGNA, 09/08/2021

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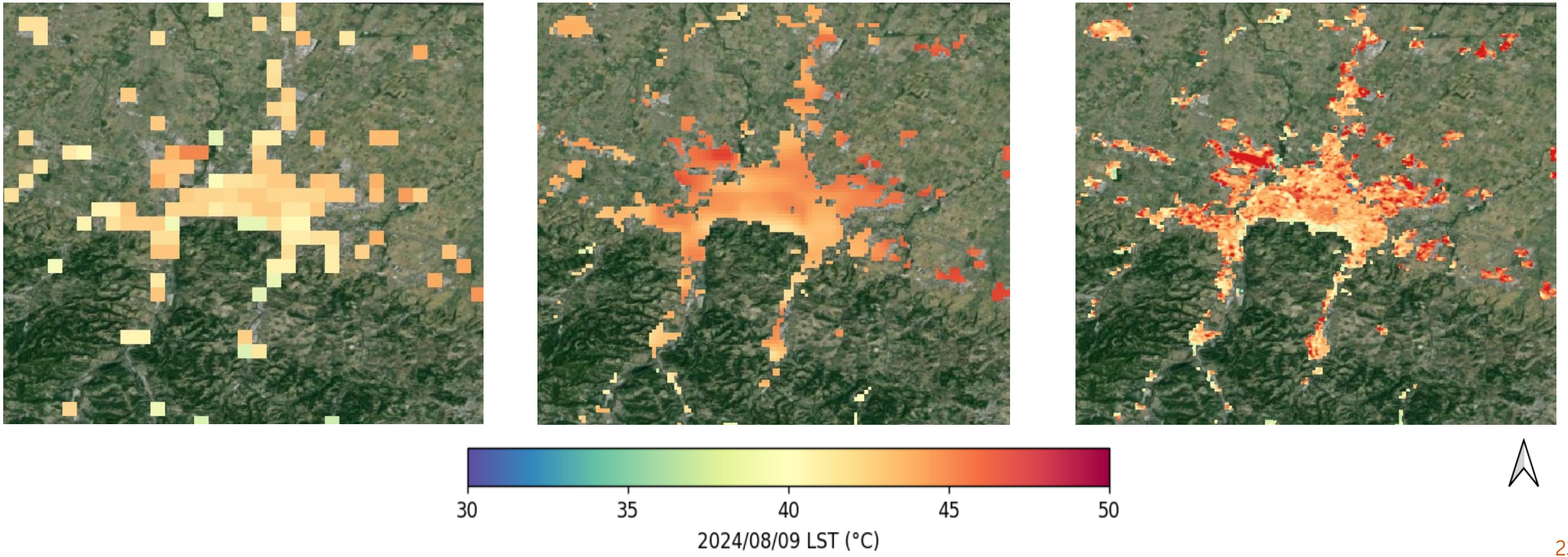
Sentinel-3 LST

Super-resolution

Landsat 8/9



Results

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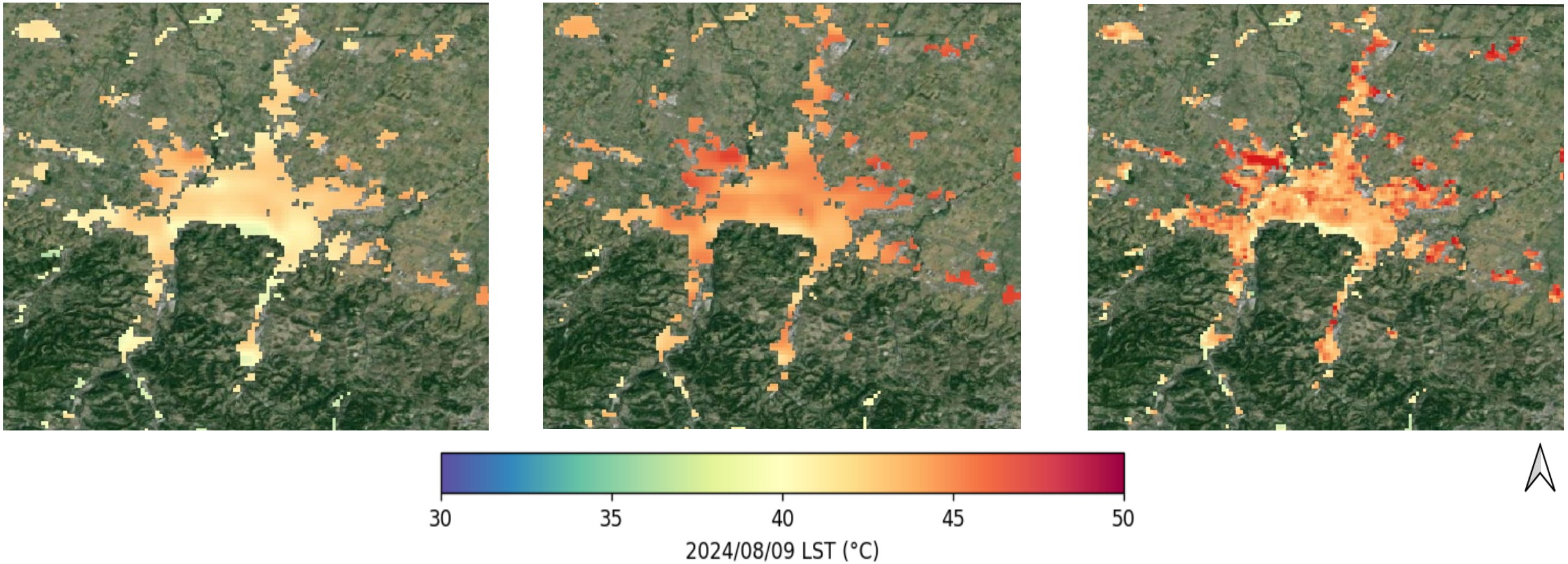
Sentinel-3 LST 300m

Super-resolution

Landsat 8/9 300m



Results

ROMA, 04/04/2024

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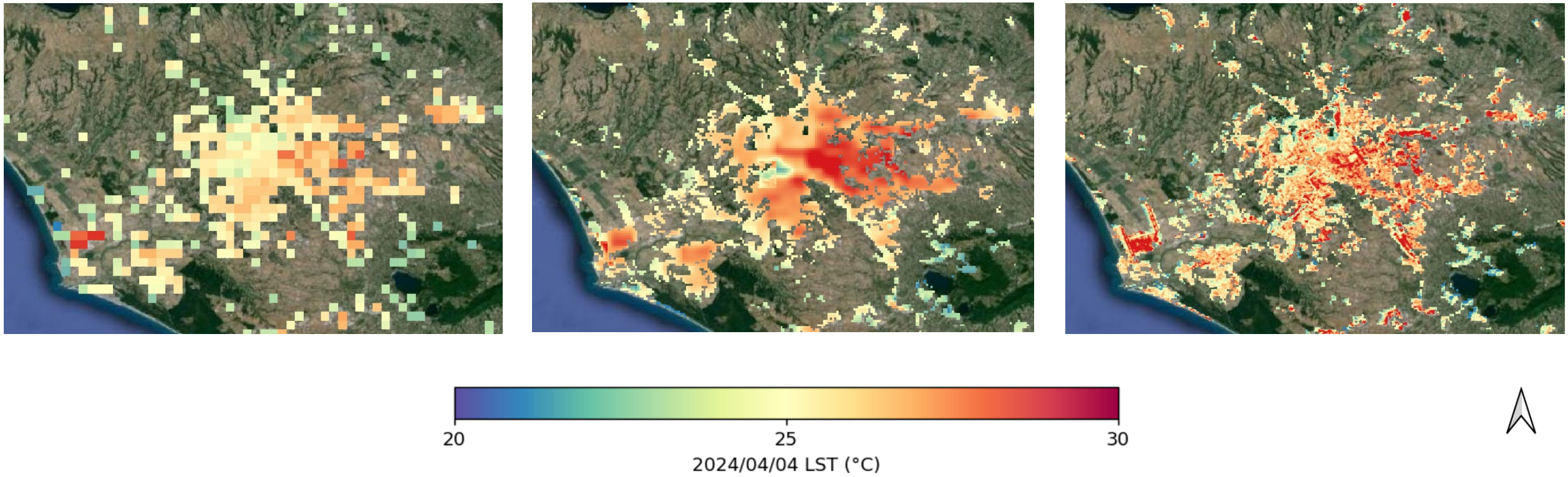
Sentinel-3 LST

Super-resolution

Landsat 8/9



Results

ROMA, 04/04/2024

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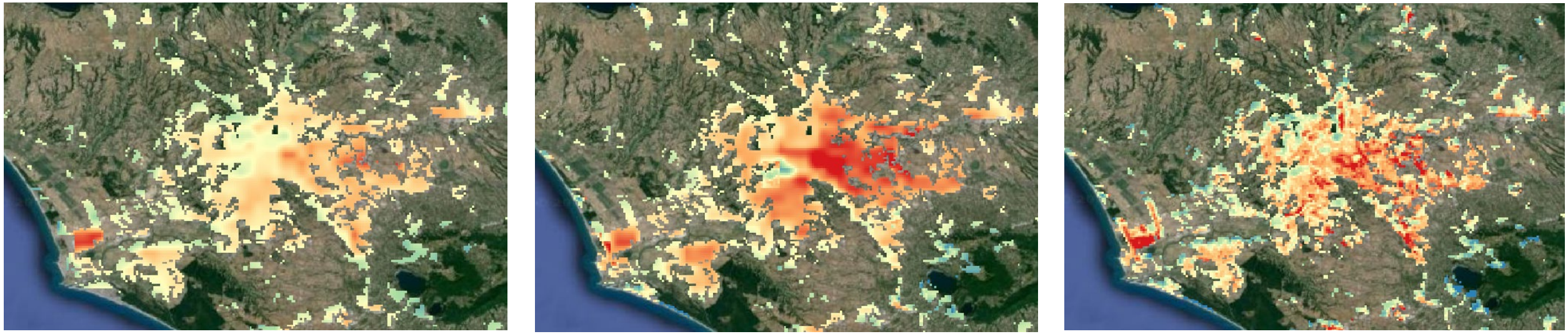
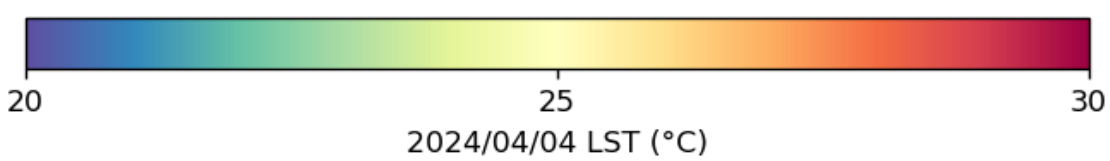
Sentinel-3 LST 300m

Super-resolution

Landsat 8/9 300m





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Take home messages and next steps

TAKE HOME

- A simplified SR approach can be designed and applied to S5P L1 and S3 L2 data using MLP
- Preliminary results shown good approximation of HR and LF data starting from LR and HF
- Performance on urban areas seems more accurate than over vegetation

NEXT STEPS

- Improve spatial resolution in output (e.g. up to 100 m for LST) --> De Santis et al., in prep
- The generated HR and LF data can be exploited for real application such as:
  - Methane retrieval with generated PRISMA data
  - Urban heat island monitoring with generated Landsat data

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THANK YOU!
Any question?

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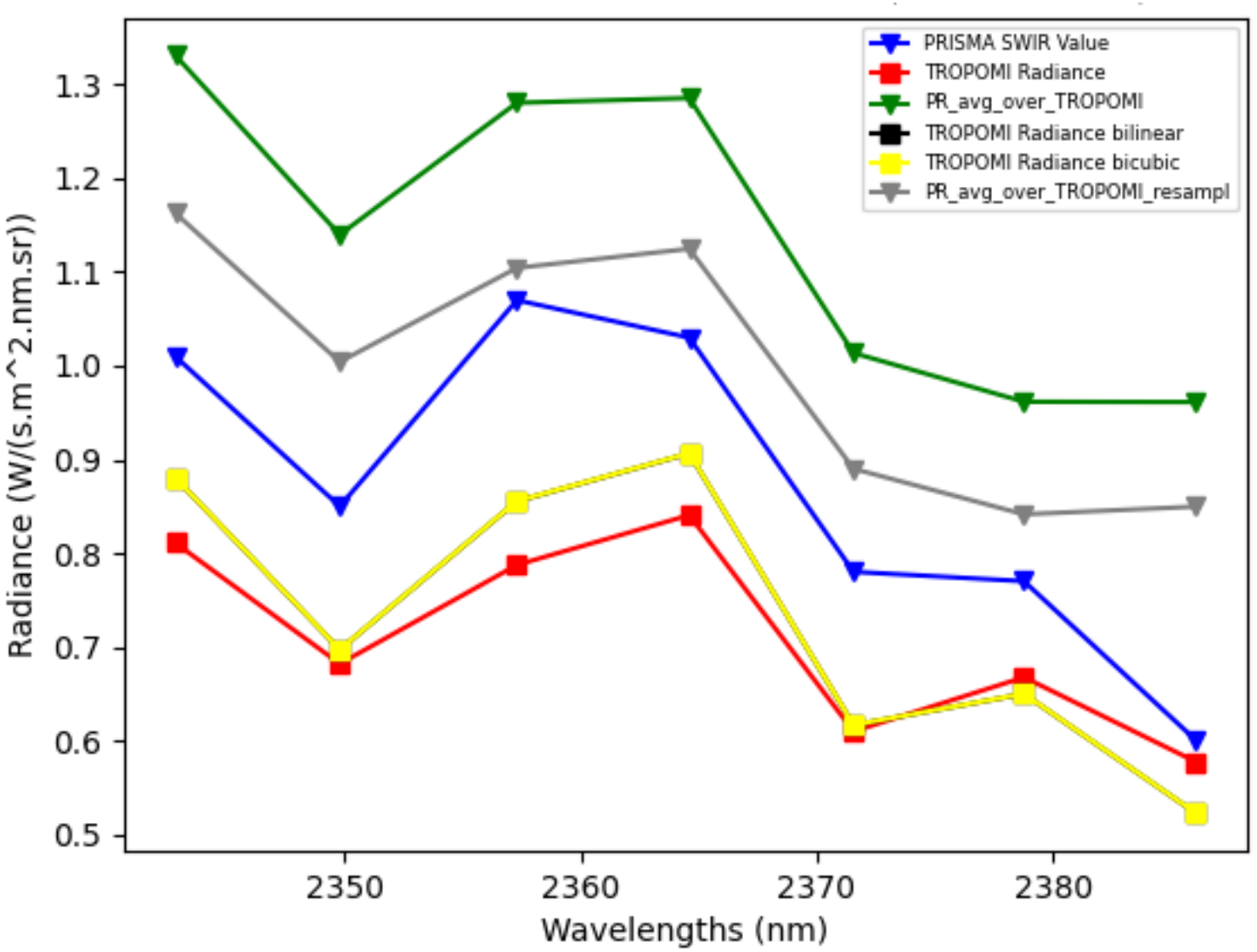
Methodology – Dataset generation S5P with PRISMA



Random example over an urban area

Extra (some literature)

Generating Daily Land Surface Temperature Downscaling Data Based on Sentinel-3 Images	https://www.mdpi.com/2072-4292/14/22/5752	Model-Based Super-Resolution for Sentinel-5P Data (Carbone et al.,)	https://ieeexplore.ieee.org/document/10499875
Assessment of High-Resolution LST Derived From the Synergy of Sentinel-2 and Sentinel-3 in Agricultural Areas	https://ieeexplore.ieee.org/document/10327786	UNDERSTANDING THE VALUE OF HYPERSPECTRAL IMAGE SUPER-RESOLUTION FROM PRISMA DATA	https://ieeexplore.ieee.org/abstract/document/10283013
Optically Enhanced Super-Resolution of Sea Surface Temperature Using Deep Learning	https://ieeexplore.ieee.org/document/9487005	**Multispectral and Hyperspectral Image Fusion by MS/HS Fusion Net**	https://ieeexplore.ieee.org/document/8953470