Agenzia Spaziale Italiana

SPACE IT UP!

Space It Up!

SPOKE 7: SPACE FOR THE SUSTAINABLE DEVELOPMENT OF THE PLANET

Politecnico di Torino

ISPRS GEOSPATIAL WEEK 2025 DUBAI

POLITECNICO MILANO 1863

Tutorial: urban monitoring and analysis with remote sensing and spatial information technology

Air Pollution

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https://bit.ly/GSW_2025_AQ_slides

6th April 2025 I Geospatial Week 2025 I Dubai

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www.gisgeolab.polimi.it

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Contents

Today's slides are here:

https://bit.ly/GSW_2025_AQ_slides

Introduction to Urban Air Quality and Remote Sensing

Urban Air Quality: Why It Matters

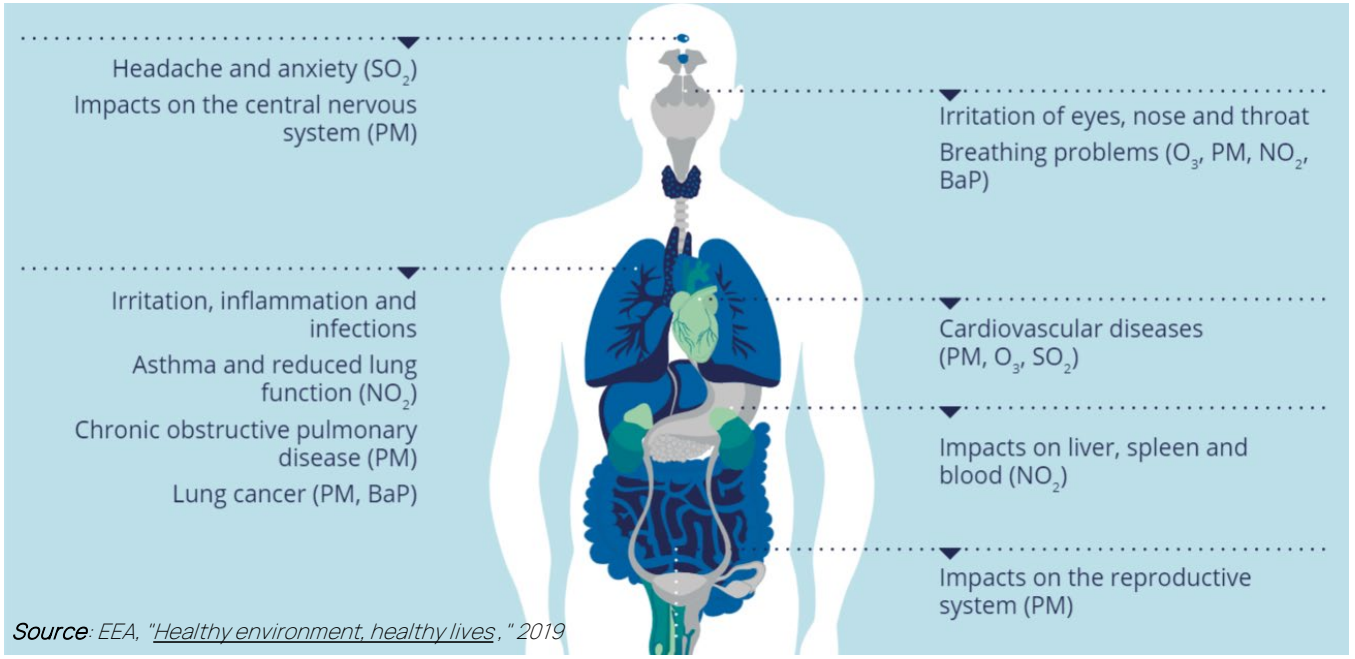
Impact on Health:

- Air pollution causes respiratory diseases, cardiovascular issues, and premature deaths.
- WHO estimates that 7 million premature deaths annually are linked to air pollution.

Environmental Impacts:

- Decreased urban visibility (smog) and reduced sunlight.
- Contribution to climate change through aerosols and greenhouse gases.
- Harming forests, wildlife, and agriculture.

What are the WHO air quality guidelines?



***Source**: EEA, "Healthy environment, healthy lives," 2019*

- 99% of the world's population live in places where air pollution levels exceed WHO guideline limits.
- In 2022, 96% of the urban population was exposed to concentrations of fine particulate matter above the health-based guideline level set by the WHO.
- All EU countries reported levels of ozone and nitrogen dioxide above the health-based guideline levels set by the WHO.

The Challenge of Monitoring Urban Air Quality

What?

Gases

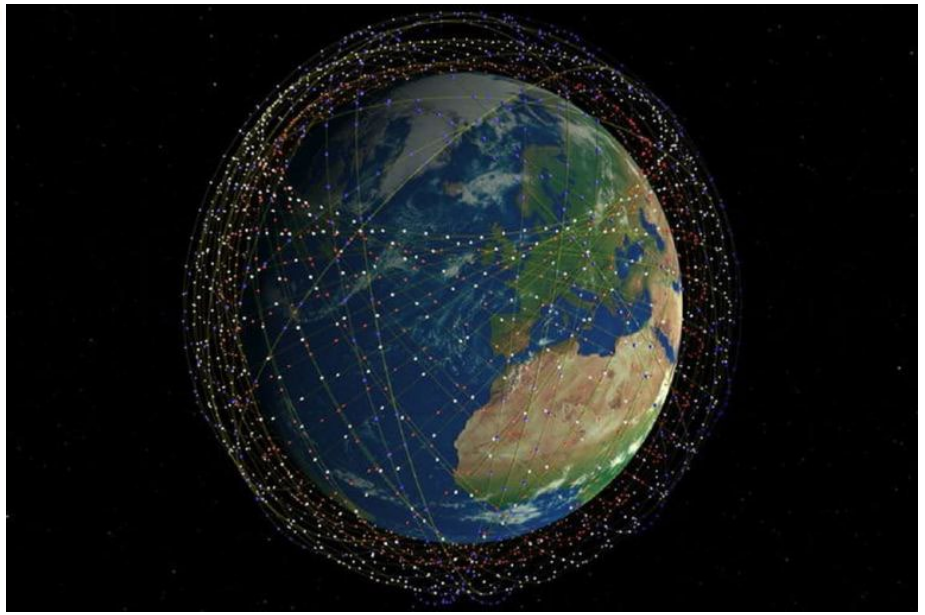
- Ozone (O3)
- Carbon Monoxide (CO)
- Nitrogen Dioxide (NO2)
- Sulfur Dioxide (SO2)
- Greenhouse Gases (CO2, Methane)

Aerosols

Fine particulates ($PM_{2.5}$)

Coarse particulates (PM_{10})

https://open.lib.umn.edu



https://www.universetoday.com/

How do we monitor?

- Ground-based monitors
- Sensors networks
- Models – statistical and physical
- Satellite remote sensing

Limitations

- Limited spatial coverage with ground-based stations.
- High cost of deployment and maintenance.
- Low-cost sensors increase monitor density but may be insufficient in heavily affected areas

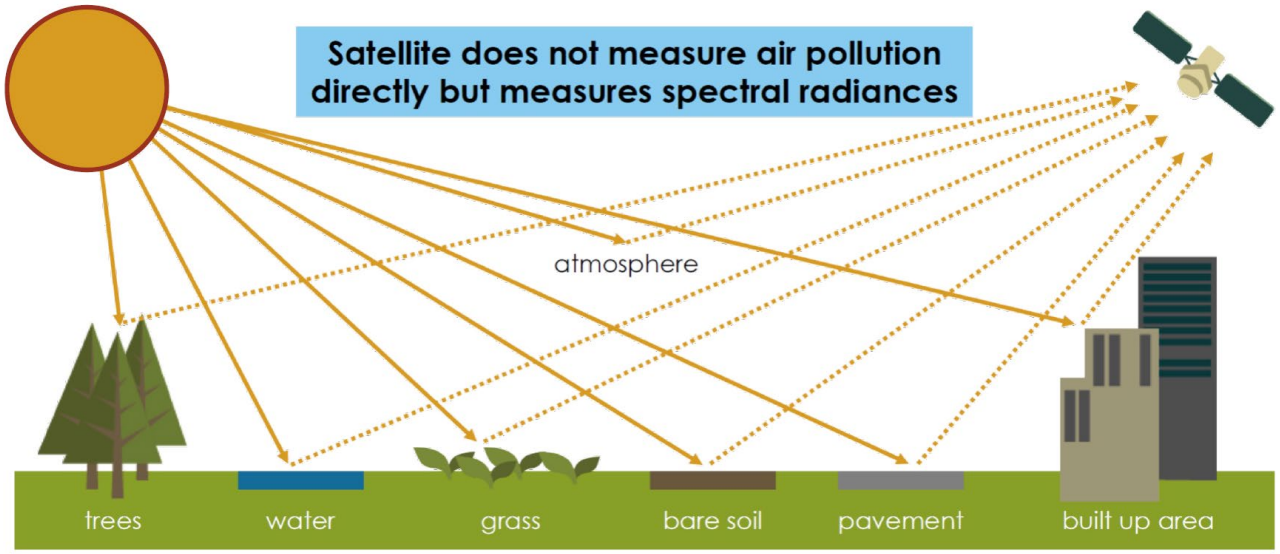
Remote Sensing as a Solution

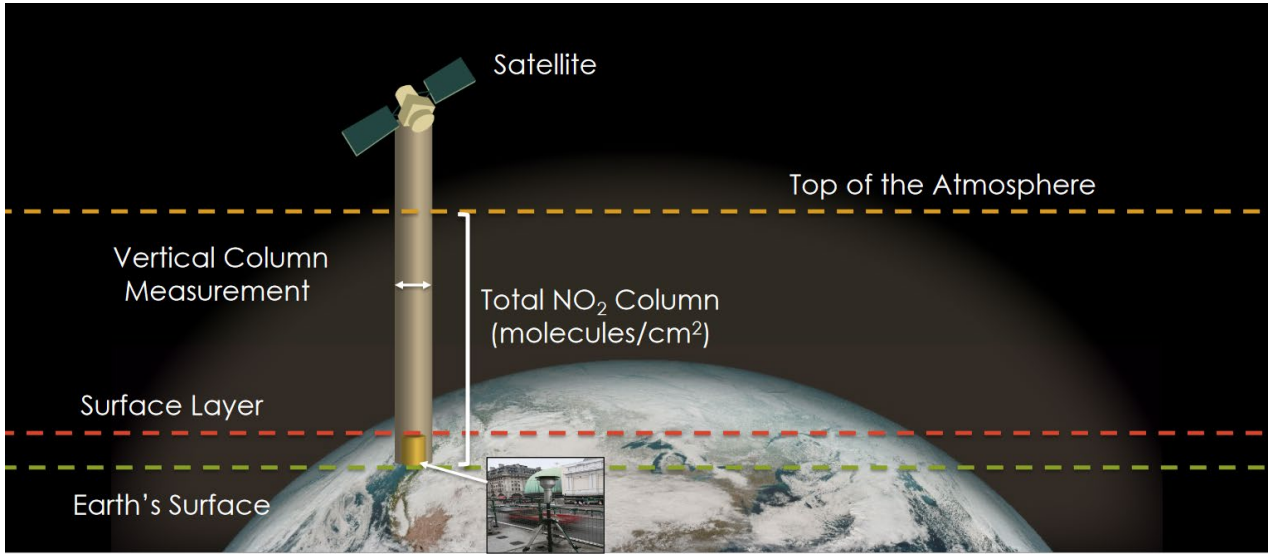
Advantages:

- Satellite-based data provide comprehensive spatial coverage.
- Temporal consistency ensures regular monitoring of pollutant trends.
- Improving spatial resolution.
- Satellites monitor trace gases (NO_2, CO, O_3, CH_4) and aerosols globally.
- Consistent data supports:
- Detecting pollution sources.
- Analyzing trends over time.
- Overpass time - polar-orbiting (1-2 days) and geostationary (continuous daytime) satellites.

Limitations:

- Night – require sunlight.
- Clouds and smoke – most instruments are blocked.
- "Nose Level" - measure the atmosphere, not just surface.

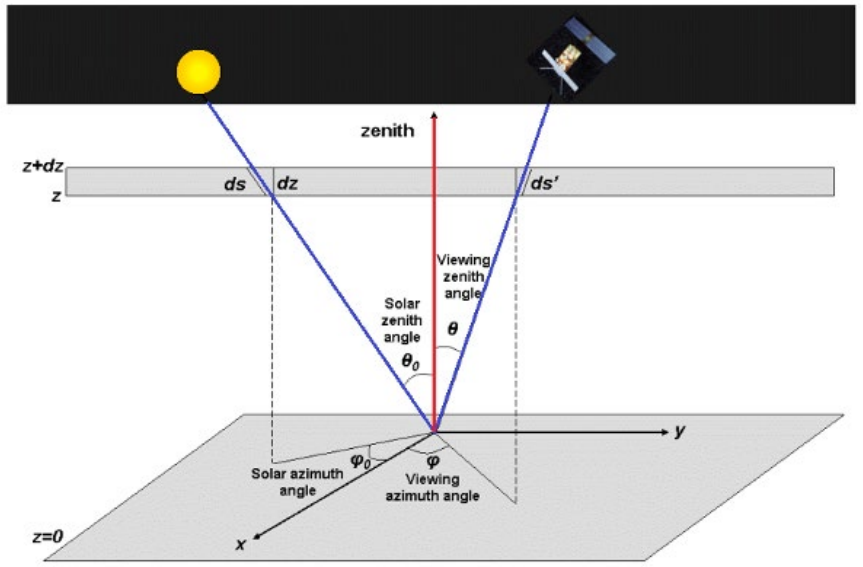




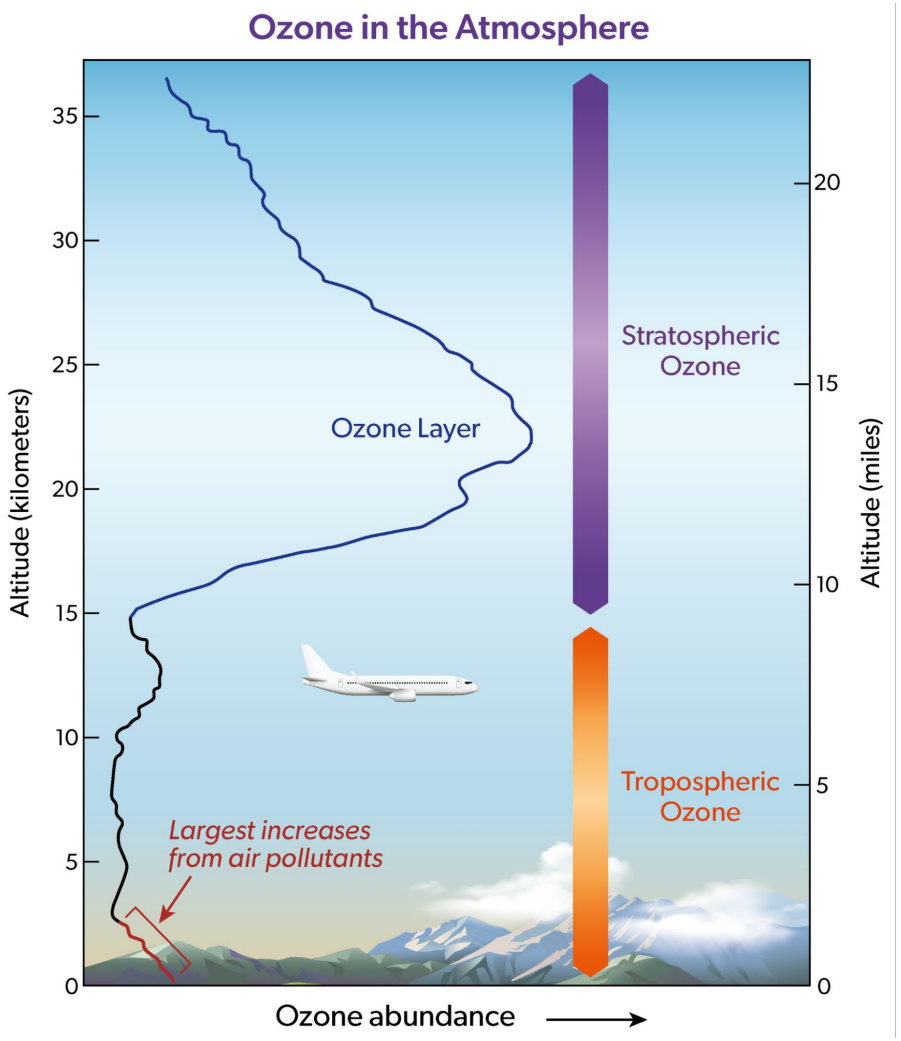
https://appliedsciences.nasa.gov/

Remote Sensing as a Solution – column products

- **Total Column**: The total amount of a gas (e.g., NO_2) integrated vertically from the Earth's surface to the top of the atmosphere.
- **Tropospheric Column**: The portion of the total column that is located within the troposphere, where most air pollution and weather phenomena occur.
- **Stratospheric Column**: The portion of the total column that resides in the stratosphere, typically dominated by background NO_2 from natural processes.
- **Slant Column**: The total amount of a gas measured along the satellite sensor's line of sight before applying atmospheric corrections.



Source: sentiwiki.copernicus.eu

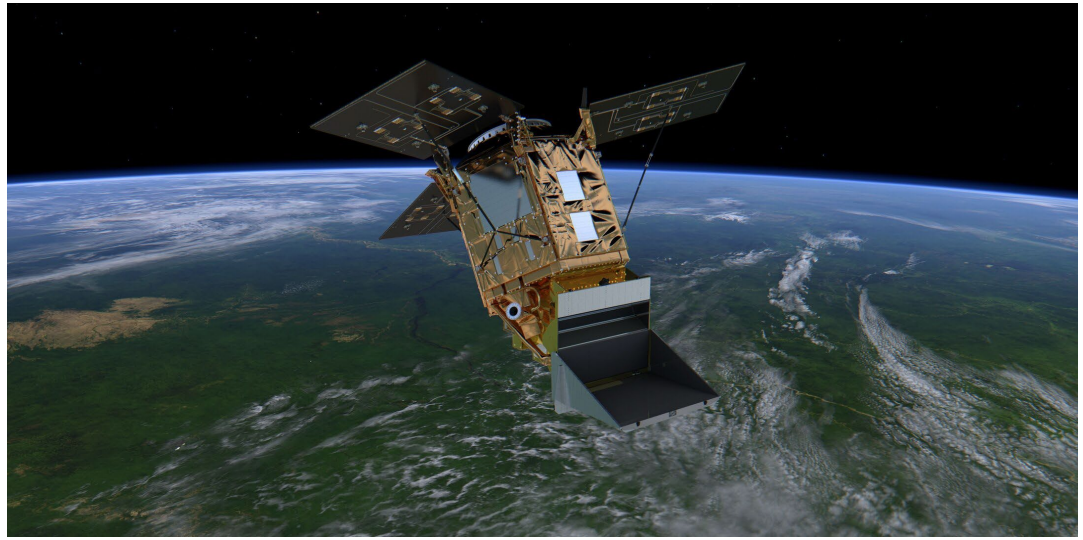


Source: eoportal.org

More details for Sentinel- 5p processing can be found here.

Overview of Satellite Missions and Data Repositories

Satellite Missions for Air Quality Monitoring



Sentinel-5P (TROPOMI):

Specialized in atmospheric monitoring.
Detects NO_2, CO, SO_2, CH_4, aerosols, and more.
Spatial resolution (~5.5x3 km per pixel).

MODIS (Aqua/Terra):

Monitors atmospheric aerosol properties (e.g., Aerosol Optical Depth).
Wide swath coverage (~2330 km).
Spatial resolution (~10x10 km per pixel).

OMI (Aura):

Measures ozone, NO_2, and other trace gases.
Heritage mission, supporting long-term data continuity.

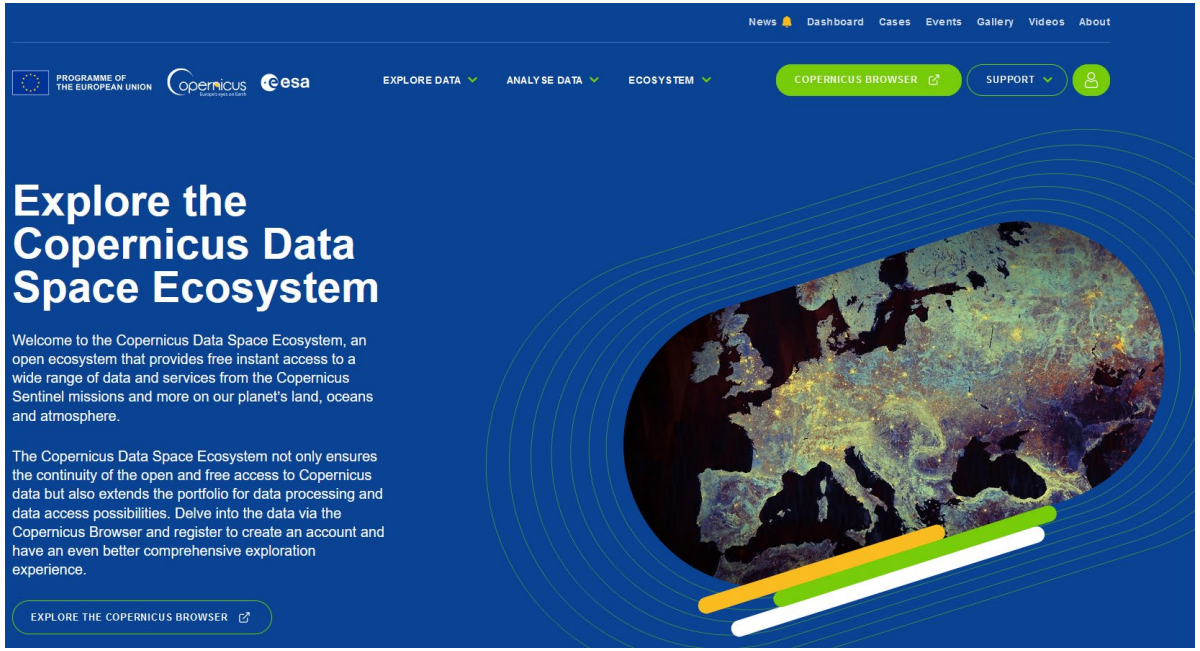
Mission	Key Focus	Resolution	Applications
Sentinel-5P	Trace gases	~5.5x3 km	Urban air quality
MODIS	Aerosols	~10 km	Global pollution
OMI (Aura)	Ozone, NO_2	~13 km	Long-term trends

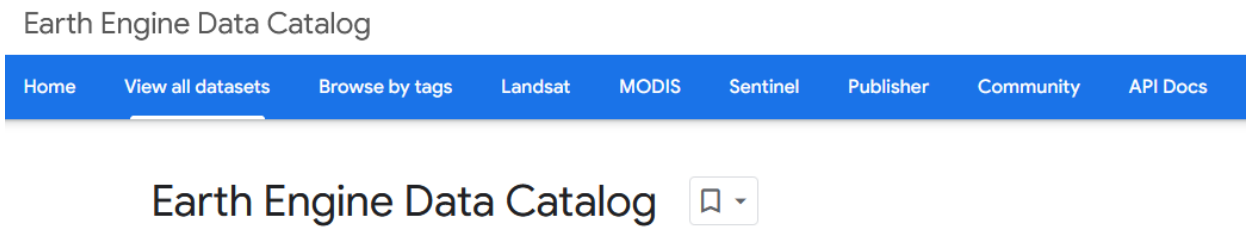
How to Access Satellite Data for Air Quality

Copernicus Data Space Ecosystem:
Primary source for Sentinel-5P products.
Offers NO_2, CO, O_3 data in NetCDF format.
Access it from here.

NASA Earthdata:
Data from MODIS, OMI, and other missions.
Easy integration with tools like Python.
Access it from here.

Google Earth Engine (GEE):
Cloud-based geospatial platform.
Provides Sentinel-5P and MODIS datasets.
Allows real-time visualization and analysis.
Access it from here.





APIs and Tools for Air Quality Analysis

Copernicus APIs:

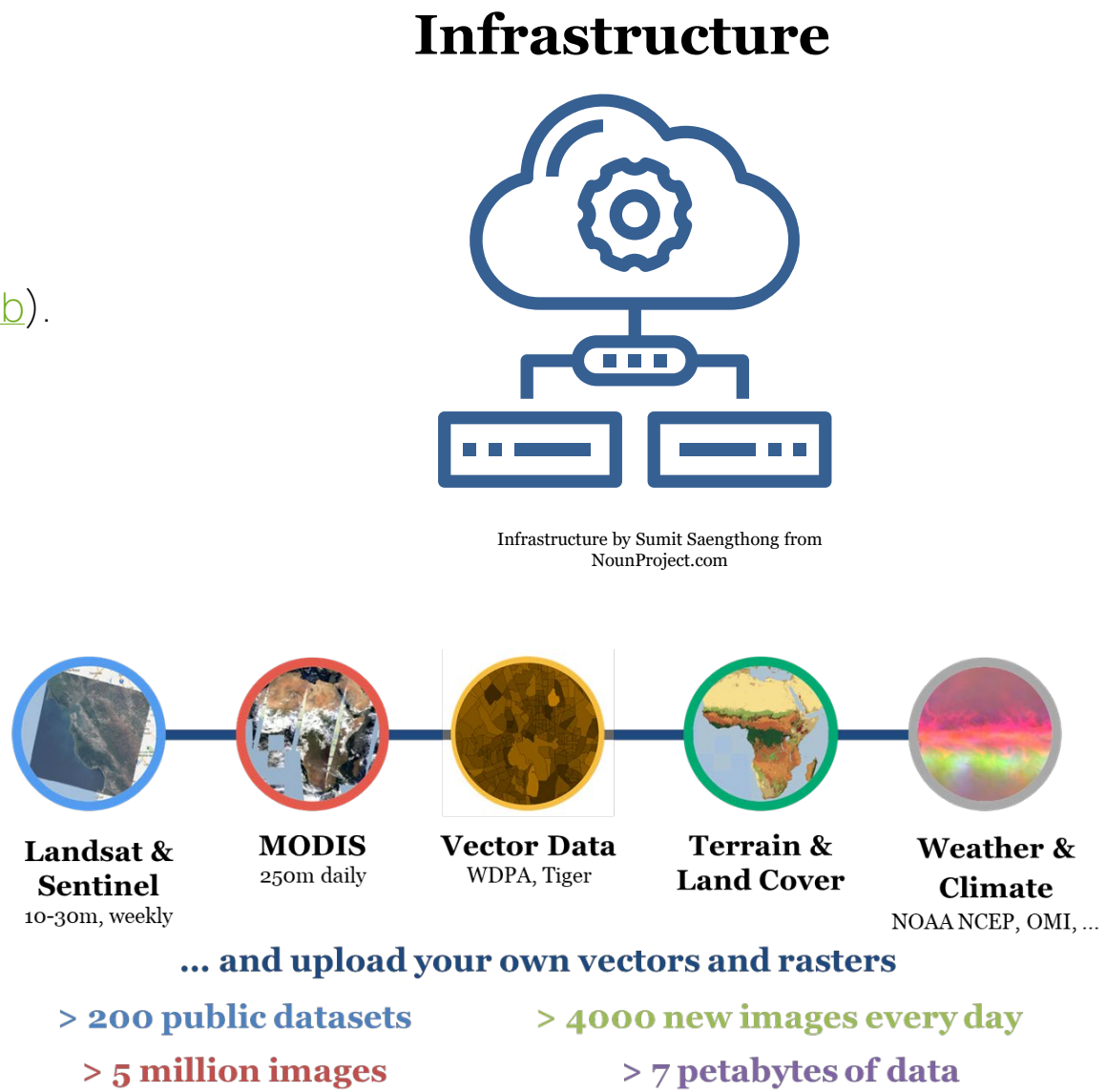
Programmatic access to Copernicus data (API and JupyterHub).
Useful for automated workflows.

Google Earth Engine API:

Simplifies integration of Sentinel and MODIS datasets.
Supports JavaScript and Python (via ee package).

Other Tools:

ESA SNAP Toolbox: Preprocess Sentinel data.
Python libraries (e.g., xarray, geemap).



Other Copernicus Services for Air Quality

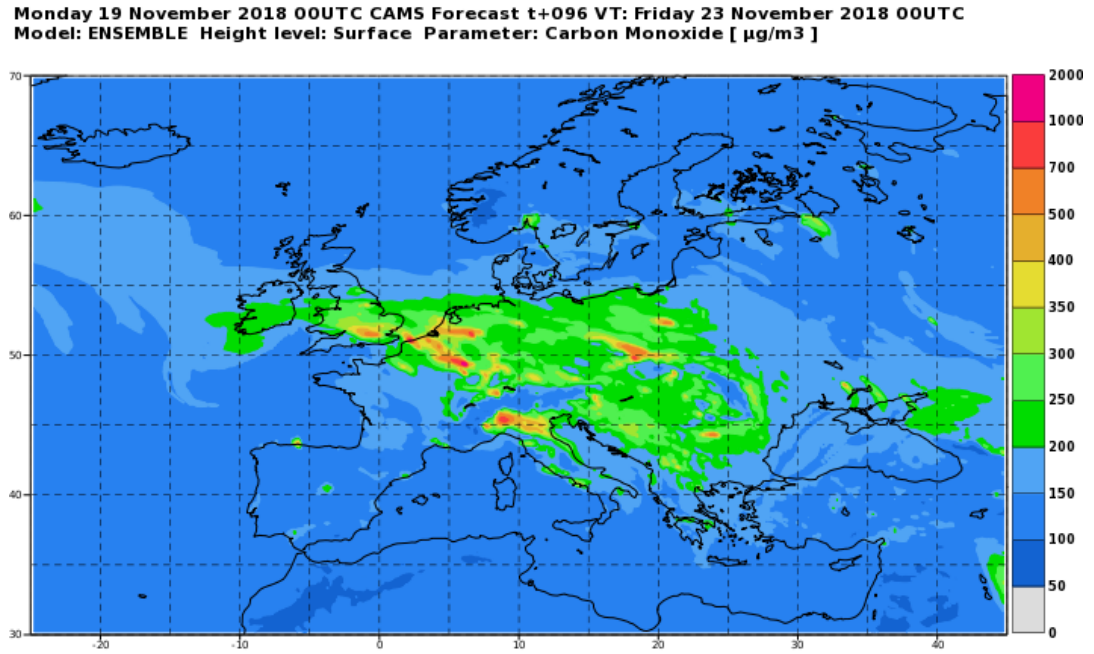
Copernicus Atmosphere Monitoring Service (CAMS):
Provides near-real-time data and forecasts.

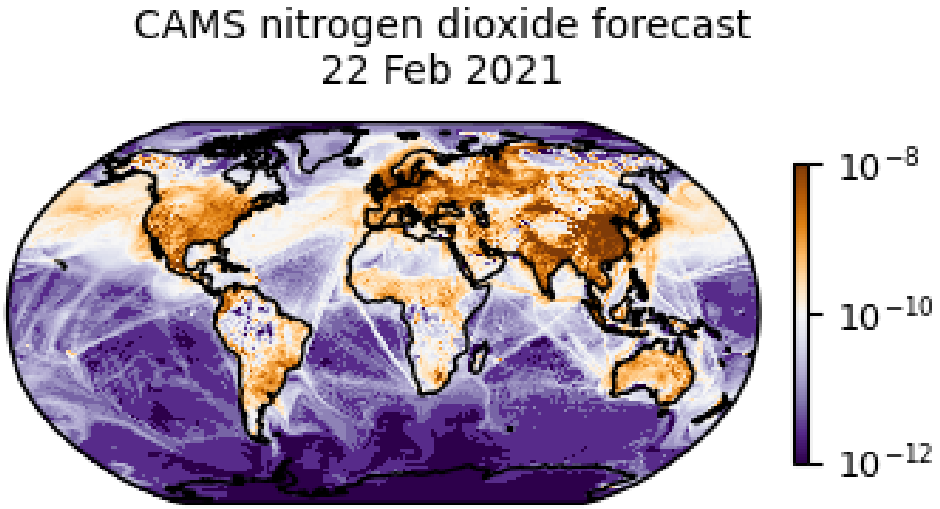
Use cases:

- air quality monitoring,
- emission tracking,
- climate modeling.

Examples of products:

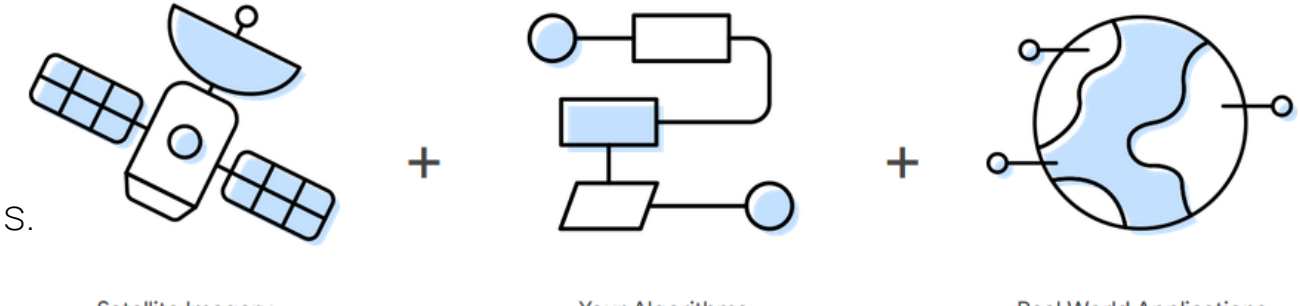
- Global atmospheric composition forecasts,
- European air quality forecasts.





Brief Introduction to Google Earth Engine

Google Earth Engine in One Slide



What is GEE?

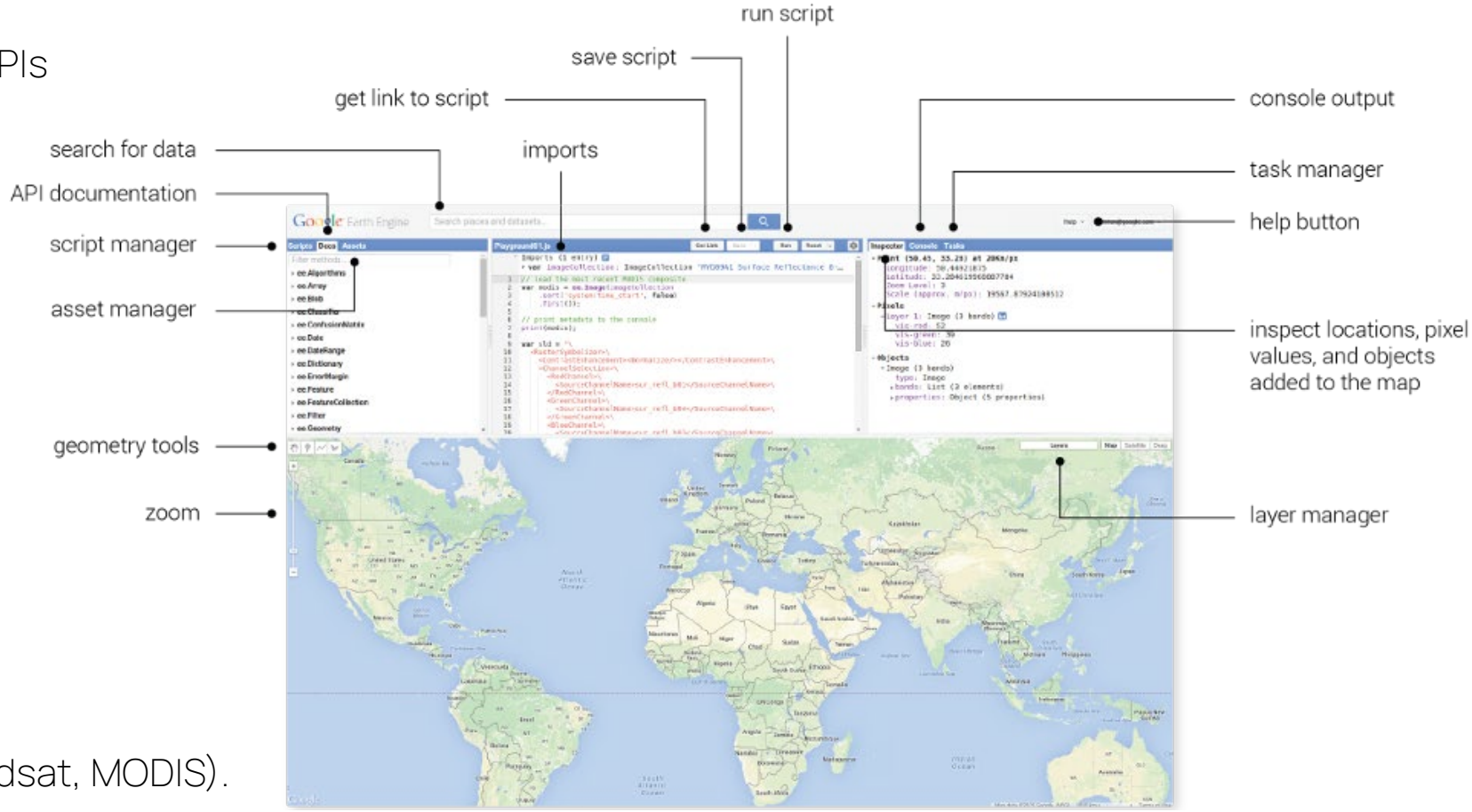
- A cloud-based platform for large-scale geospatial analysis.
- Provides access to petabytes of satellite imagery and environmental datasets.
- Offers a browser-based interface and APIs

How? - JavaScript

- Primary language for GEE's Code Editor.
- Enables fast, interactive geospatial processing and visualization.

Key Features:

- Simple scripting for tasks like filtering, mapping, and reducing datasets.
- Real-time rendering of geospatial outputs (e.g., maps, charts).
- Creation of apps.
- Built-in dataset catalogs (Sentinel, Landsat, MODIS).



Hands-on

Before we start

Registration – go to https://earthengine.google.com/ and in upper right corner select *Get Started* and follow the instructions

Setup Cloud Project – if it is not set and you haven't done it, follow the instructions *Transition to use Cloud projects*

Get Started with Earth Engine guide ← strongly recommended

Google Earth Engine Developers – helpful group to seek support

Additional resources - Earth Engine 101 - Introduction to the API, Cloud-Based Remote Sensing with Google Earth Engine

Today's scripts are available in my GEE repository
https://bit.ly/GSW_2025_GEE

Not a “Hello World” example

```
var collection = ee.ImageCollection('COPERNICUS/S5P/OFFL/L3_NO2')
  .select('tropospheric_NO2_column_number_density')
  .filterDate('2024-01-01', '2024-12-31')

var image = collection.mean()
var band_viz = {
  min: 0,
  max: 0.00010,
  palette: ['black', 'blue', 'purple', 'cyan', 'green', 'yellow', 'red']
};

Map.addLayer(image, band_viz, 'S5P N02');
Map.setCenter(9.1731, 45.4639, 6);
```

Hello NO2 script

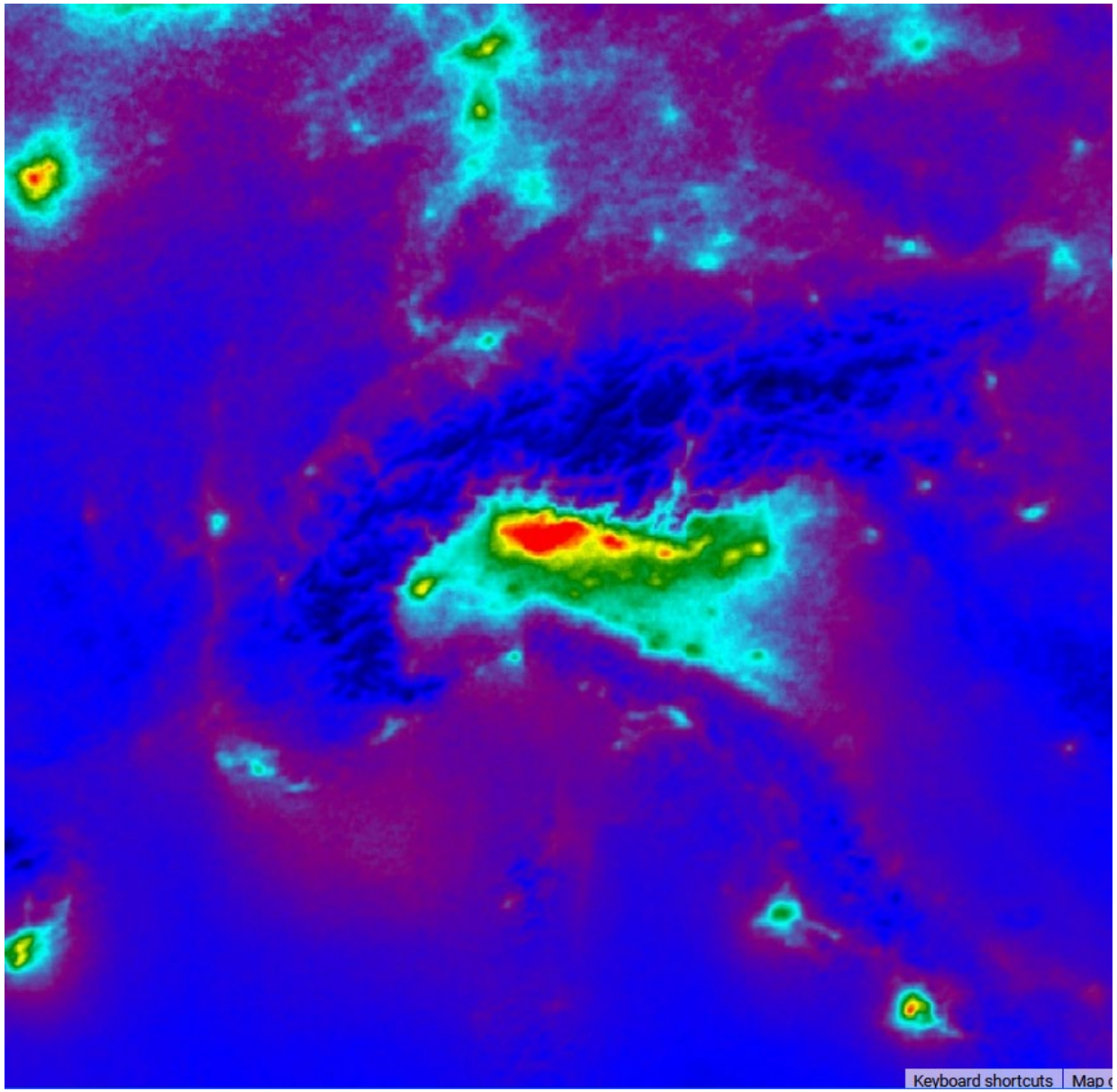
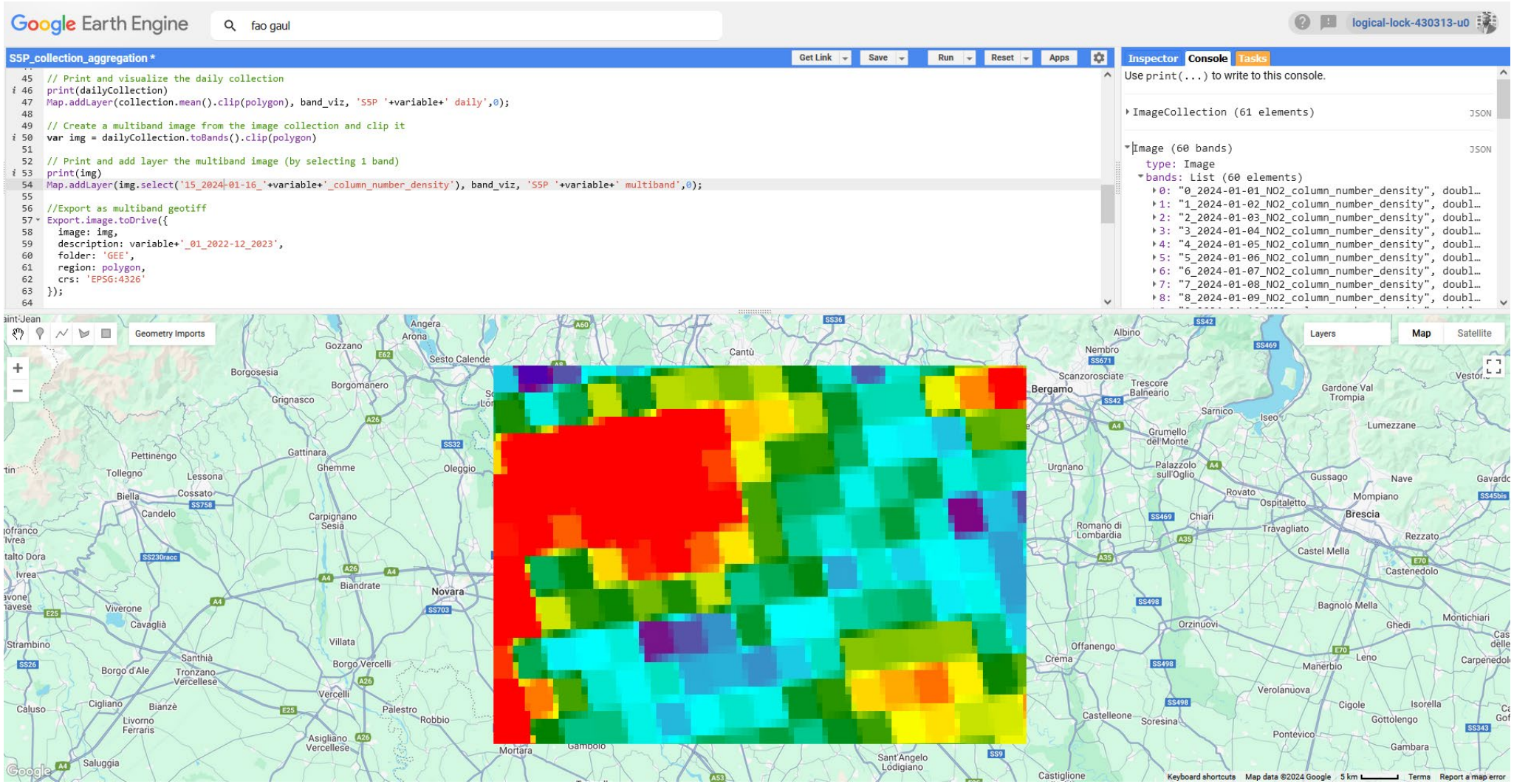
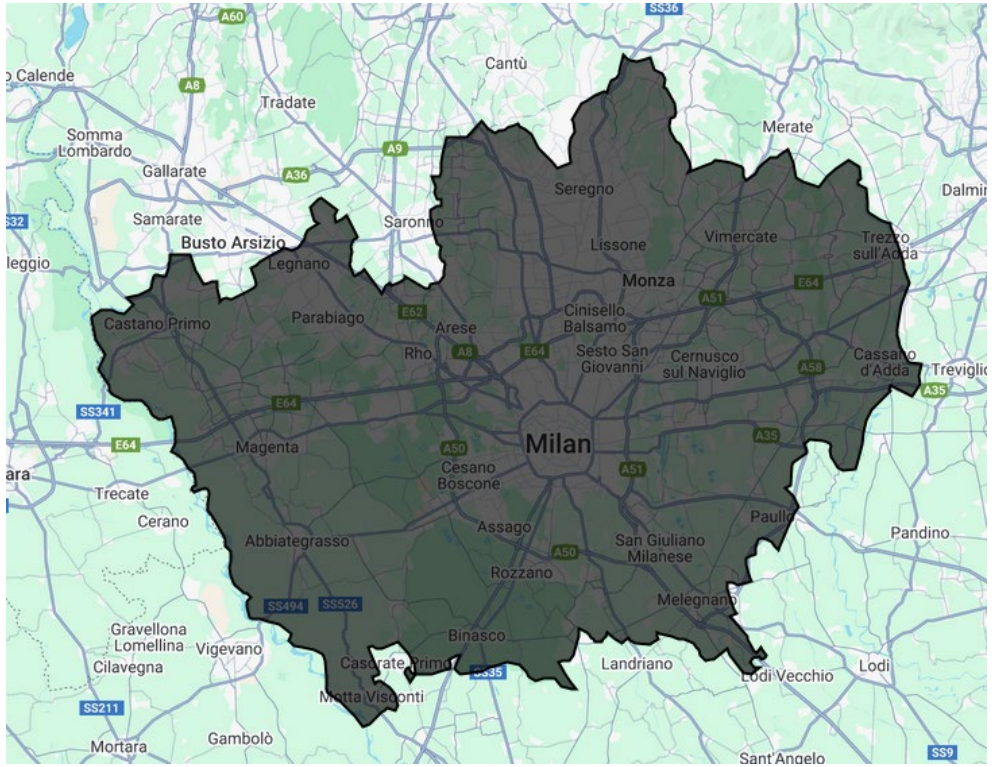


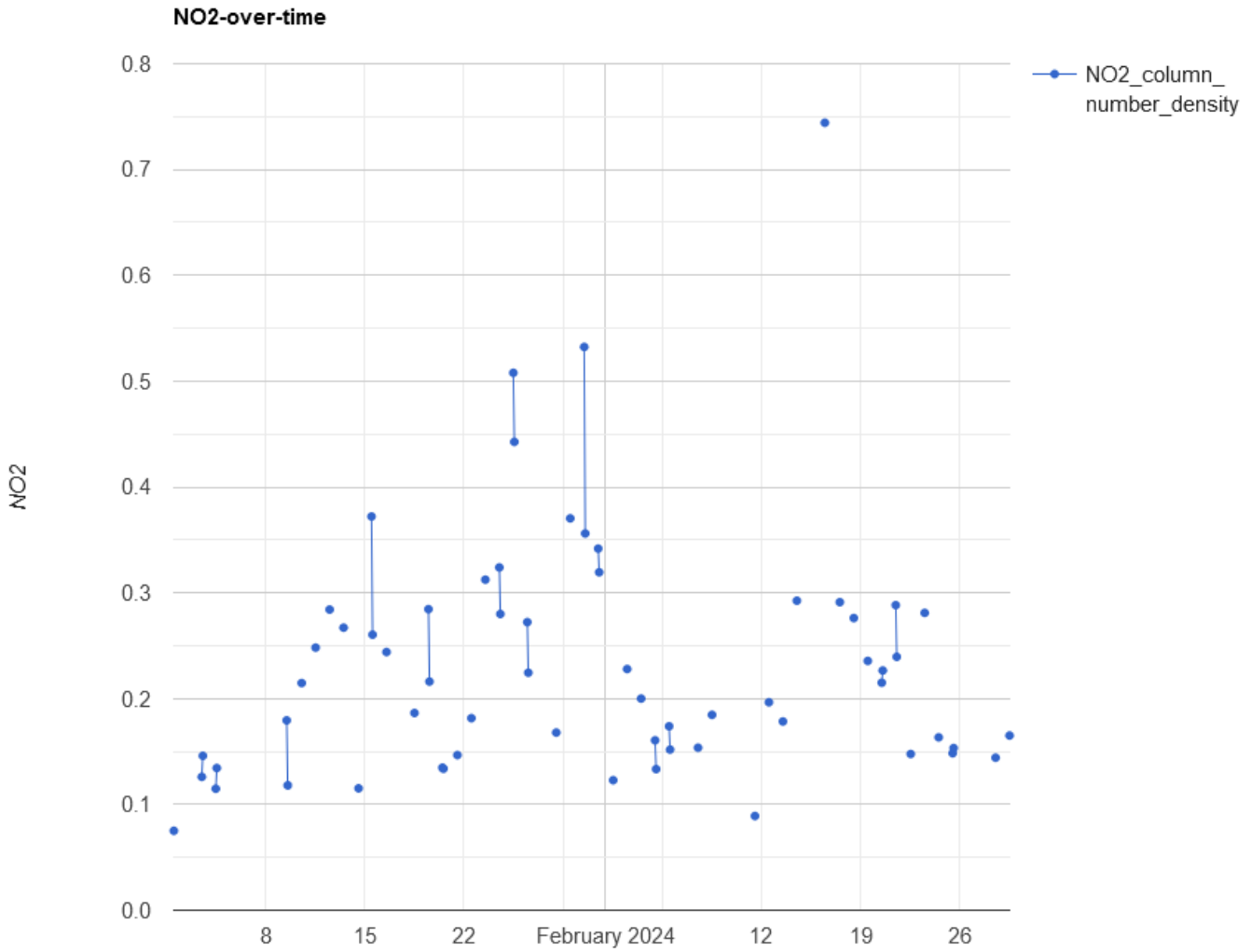
Image daily aggregation



S5P_collection_aggregation script

Time-series for specific region





S5P_collection_aggregation script

Any questions?

SPACE IT UP! Grant Agreement ASI n. 2024-5-E.0
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Thank you for your attention

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