

UM SISTEMA PARA MONITORAR A QUALIDADE DO AR A PARTIR DE DADOS DO SATELITE SENTINEL-5

A system for monitoring **air quality** using
Sentinel-5 satellite data

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Air Quality

The maintenance of a suitable environment for living beings needs good air quality.

Deterioration of air quality

- Unregulated industrial growth
- High energy consumption
- Burning fossil fuels
- Lack of rules and regulations



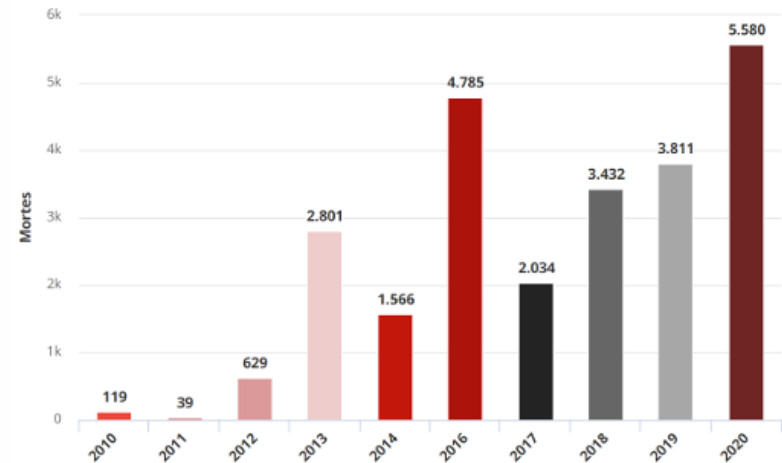
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Air Quality

A level of air quality that is unfit for breathing can be harmful to human health in many ways.

Negative impacts on health

- Irritate the airways
- Causing coughing
- Shortness of breath
- Asthma and chronic bronchitis



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Air Quality Index (AQI)

The air quality index (AQI) is a numerical value calculated.

Main air pollutants

Particulate matter (PM)
Sulfur dioxide (SO₂)
Nitrogen dioxide (NO₂)
Carbon monoxide (CO)
Ozone (O₃)
Volatile Organic Compounds (VOCs)

AQI	Air Pollution Level
0 - 50	Good
51 - 100	Moderate
101 - 150	Unhealthy for sensitive groups
151 - 200	Unhealthy
201 - 300	Very Unhealthy
301 +	Hazardous

Table: Air Quality Levels, Environmental Protection Agency

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Air Quality Index Calculation

Related to possible repercussions on the health of the population and the environment.

The AQI for each pollutants P :

$$AQI_P = \frac{I_{high} - I_{low}}{C_{high} - C_{low}}(C_{mp} - C_{low}) + I_{low} \quad (1)$$

AQI value:

$$AQI = \max(AQI_{p1}, AQI_{p2}, AQI_{p3}, \dots AQI_{pN}) \quad (2)$$

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Pollutant Data

- Ground Sensors
Measures particulate matter, refers to microscopic particles suspended in the air.
- Satellite Sensors
Capture different types of data, such as atmospheric measurements, temperature, humidity, topography, and images.

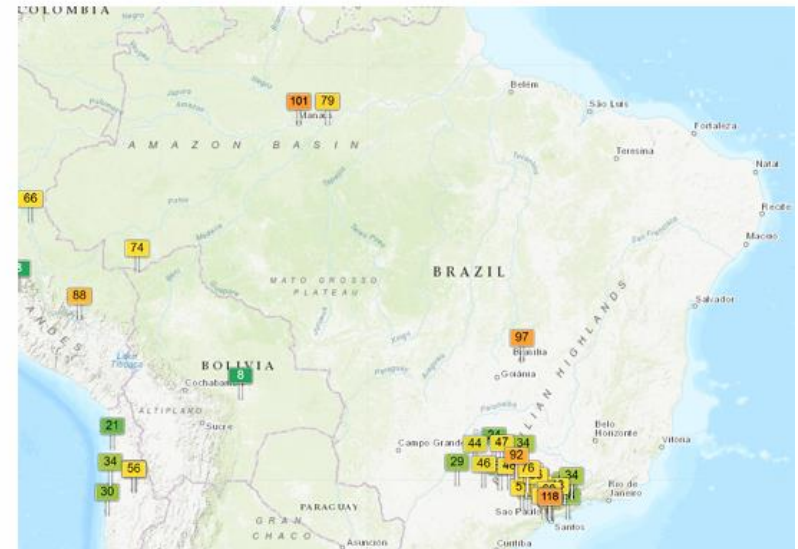


Figure: World Air Quality Index project

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Ground Data - IEMA

Present in 11 Brazilian states:

Distrito Federal (IBRAM-DF)

Bahia (SEMA-BA)

Espírito Santo (IEMA-ES)

Goias (SEMAD-GO)

Minas Gerais (FEAM)

Paraná (IAT)

Pernambuco (CPRH)

São Paulo (CETESB)

Rio de Janeiro (INEA)

Rio Grande do Sul (FEPAM)

Ceará

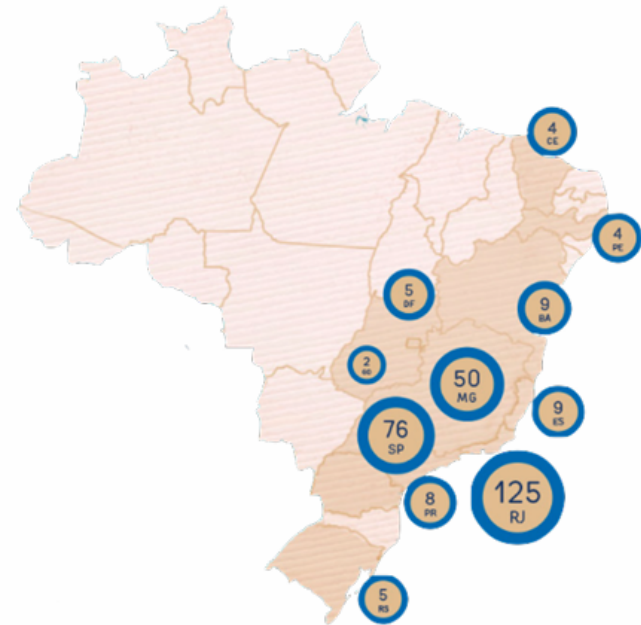


Figure: Number of monitoring stations per state.

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Ground Data - IEMA

Table: IEMA Monitoring station data.

Latitude	Longitude	Estacao1	Estado2	Poluente	...
-22,705824	-43,311861	DC-Pilar	RJ	MP10, NO2, SO2	...
-22,832162	-43,07337	SG-UERJ	RJ	MP10, SO2	...
⋮	⋮	⋮	⋮	⋮	⋮

Table: Sample of how are the IEMA data.

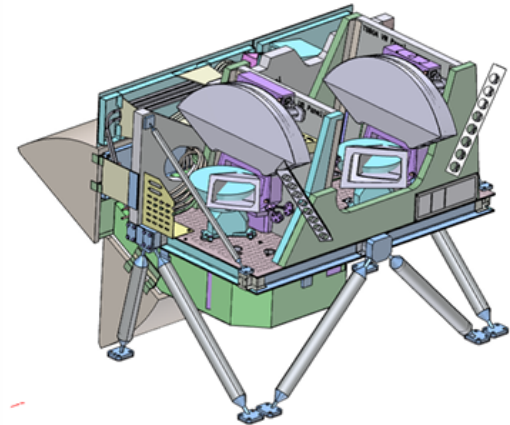
Data	Hora	Estacao	Codigo	Poluente	Valor	Unidade	...
2019-01-01	00:00	DC-Pilar	RJ21	NO2	6.087099	µg/m3	...
2019-01-01	01:00	DC-Pilar	RJ21	NO2	6.387664	µg/m3	...
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮

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Satellite Data - Sentinel-5

Sentinel-5 is a low-orbit earth satellite system designed to provide information on air quality and climate composition.

- It forms part of the European Earth Observation Program “Copernicus”
- Focuses on air quality and climate composition
- High resolution spectrometer system, operating in the ultraviolet to infrared range.



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Satellite Data - Sentinel-5

- Cover almost the entire solar irradiance spectrum (240 to 2400 nm)
- Main climatic components O_3 , NO_2 , SO_2 , $HCHO$, CO , CH_4
- The height of the satellite orbit is 817 km, the distance of the track on the ground is 2670 km
- Spectral sampling of 7x7 km

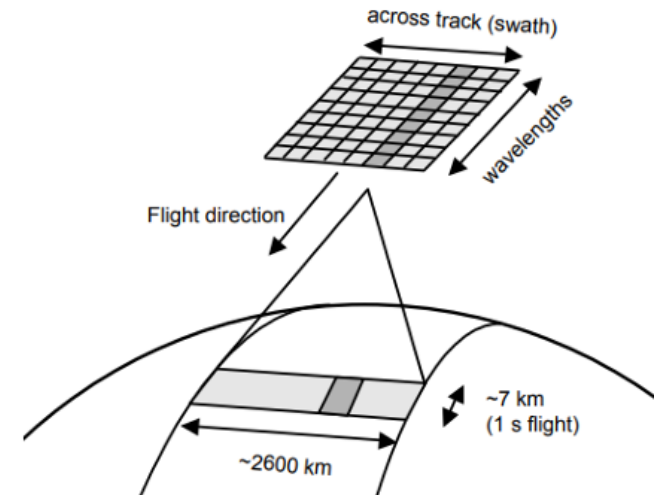


Figure: Measurement principle

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Strictly Related Work

Use of geographic information together with Sentinel-5 data

Wang et al., 2023 Investigates spatial and temporal variations at a hyperlocal scale within a city using advanced geostatistical models.

Rudke et al., 2023 Evaluate the effectiveness of satellite data in monitoring air quality changes in São Paulo, Brazil, during the COVID-19 pandemic.

Omrani et al., 2020 Describes the creation of a new spatiotemporal dataset to monitor air pollution, specifically nitrogen dioxide (NO₂), over France.

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Problem

Lack of adequate representation of air pollution.

Perform accurate measurements in independent geographic regions.



Figure: Pollutant measurements on Rio de Janeiro, Brazil (credit: IEMA)

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Problem

Segment the pollutant indices at different levels of granularity accurately.

Granularity

- Continents
- Countries
- States
- Cities

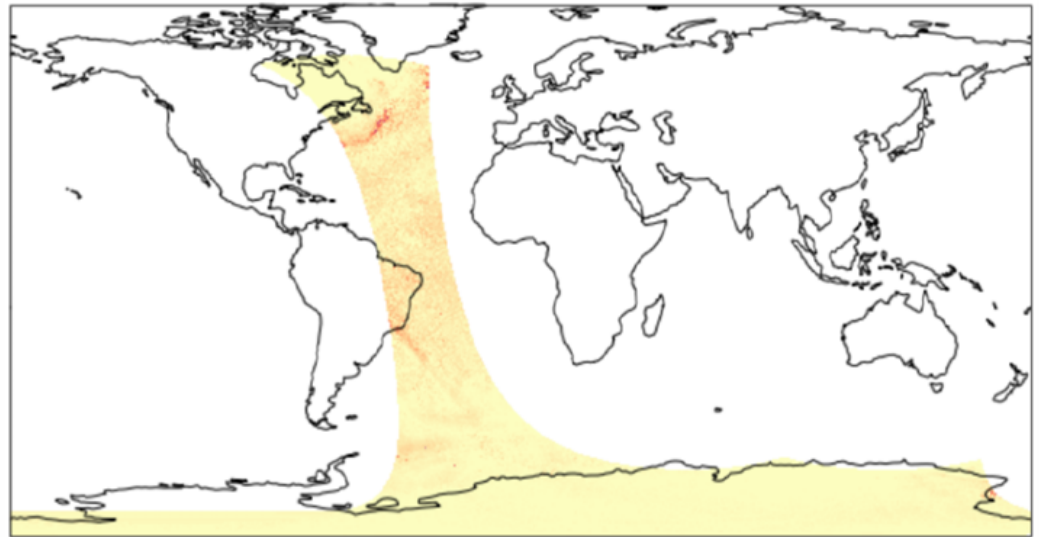
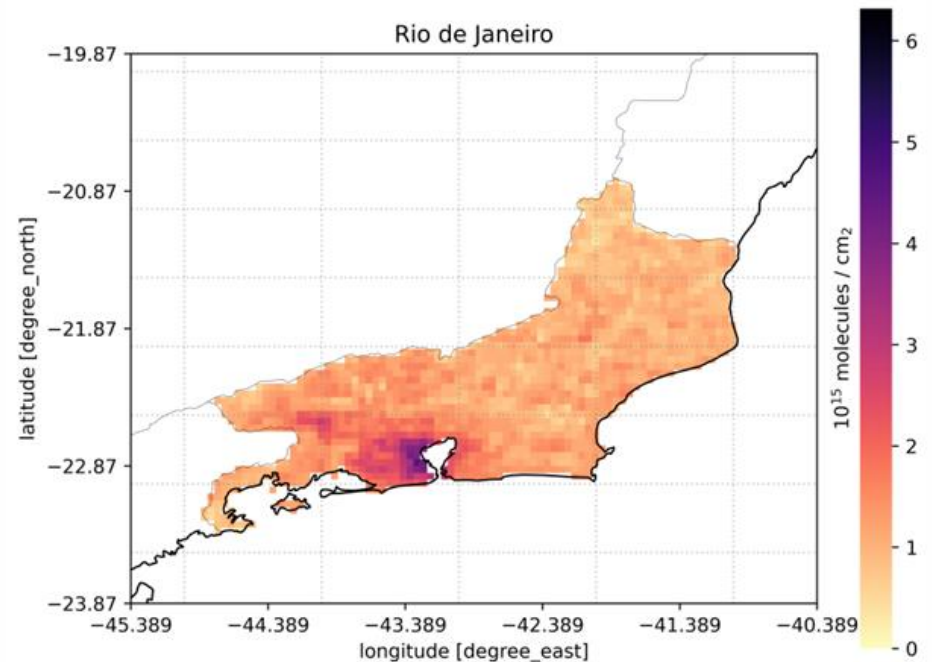


Figure: Range of data collected by Sentinel-5

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Problem

- Spatial resolution
- Data aggregation
- Temporal variability
- Correlation



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Problem

Data Quality

Data pre-processing, cleaning, remove outliers.

Normalization, standardization, adjust data to a standard scale.

Quality filter, avoids other atmospheric information.

Multi-band Approach

Integration of spectral data, combines information from spectral bands.

Temporal analysis, examines daily variations in pollutants concentrations.

Area Delimitation

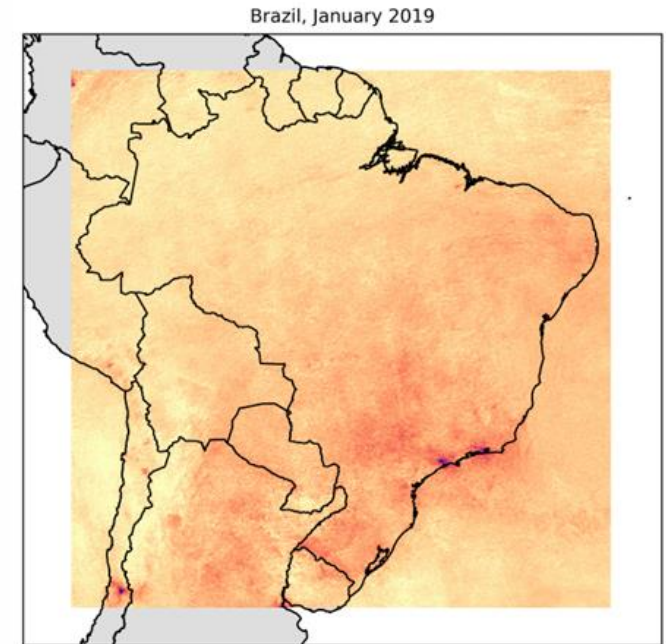
Delimitation of geographic polygon, used polygons to represent geographic limits.

Spatial filtering, exclude data outside the geographic limits.

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Motivation

Consistently obtain measurements of multiple pollutants that represent the actual pollution of a geographic region.



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Motivation

Carry out daily measurements of pollution indices for different levels of granularity.

- Measurements for different levels of granularity
- Intervals specific periods
- Comparison of intervals periods and areas

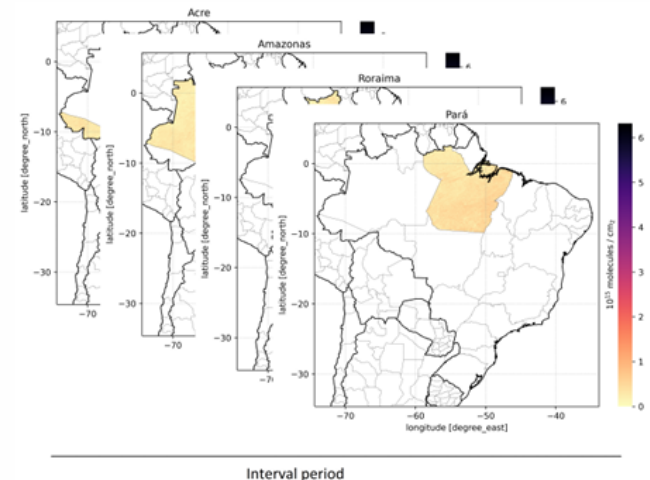


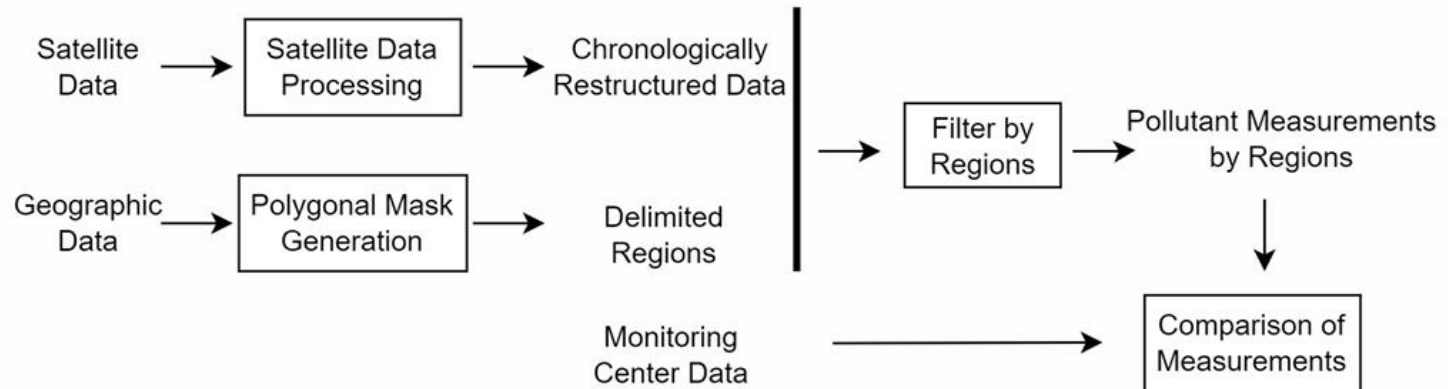
Figure: Segmentation of different regions within a time interval

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Implementation

- Temporal analysis of air pollutants for different levels of granularity

- Comparison of pollution levels between IEMA and Sentinel-5 data



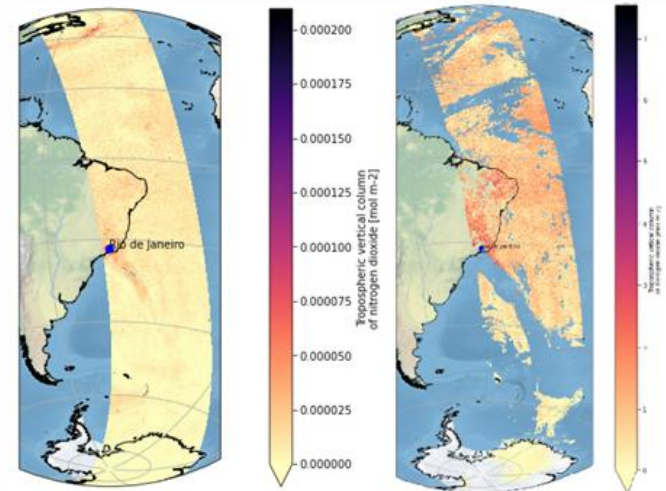
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Implementation

Data tracks generated by the Sentinel-5 sweep around the earth.

Data Processing

- Downloaded files (.nc) contain pollutant data
- Size of data tracks varies from 300MB to 500MB
- It is necessary 2 to 3 data tracks per day



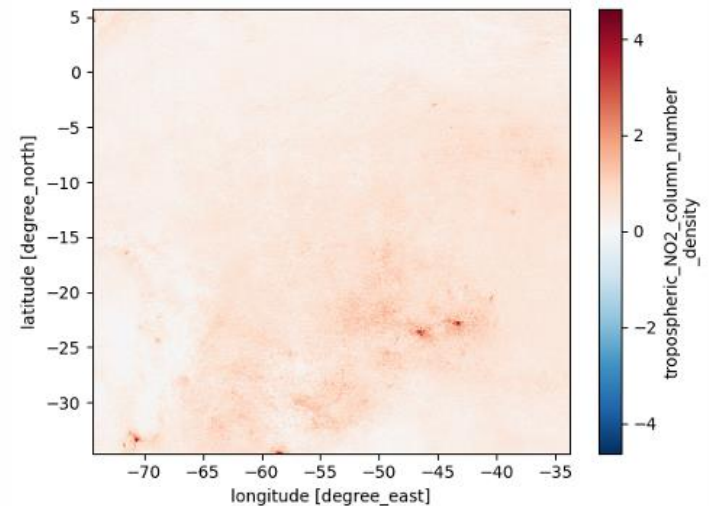
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Pipeline

Reduce and Filter .nc Files

Data Processing

- Filter data to eliminate various interferences, such as clouds and rain
- Obtains the pollutant indexes (P_{molec}/cm^2) and time data
- The delimitation of the data is defined by latitude and longitude

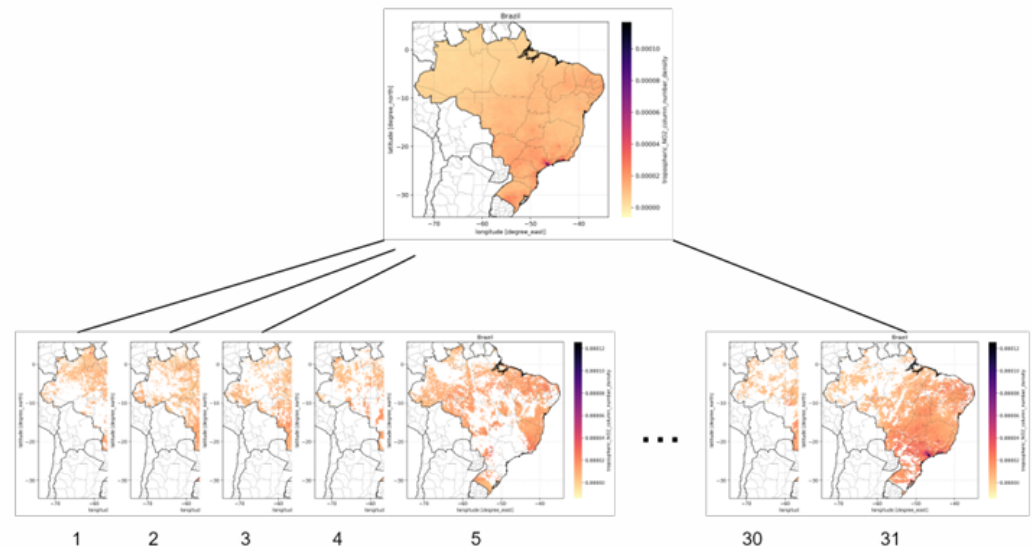


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Pipeline

Data Processing

- Chronological Ordering of Data
- The result is a list of chronologically ordered matrices
- Each matrix represents the data on a specific day



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Pipeline

Cartographic Database

- Dataset is developed containing the geographic delimitations
- Use the information of the polygons and to create polygonal masks
- Focuses analysis and measurements on defined areas

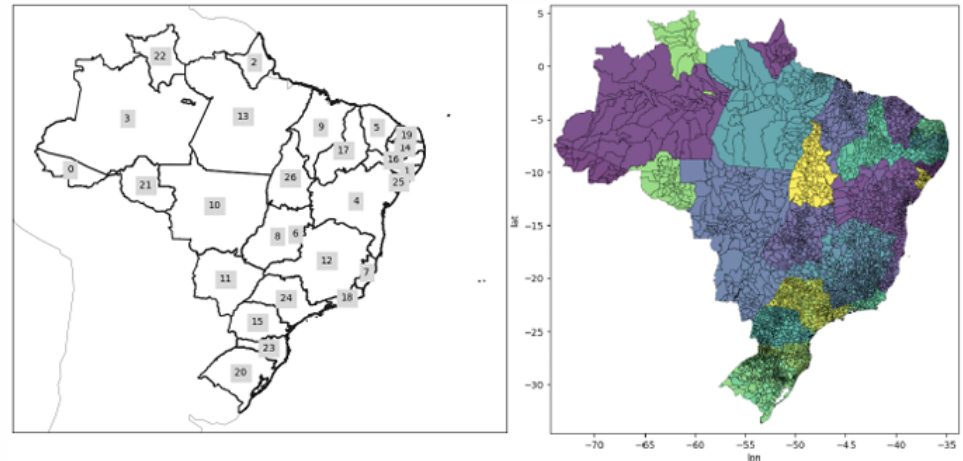


Figure: Polygonal masks of the country, states and cities

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Pipeline

Region filter

- Using the matrices of pollution indices previously sorted chronologically
- The polygonal masks are used to delimit the areas of interest

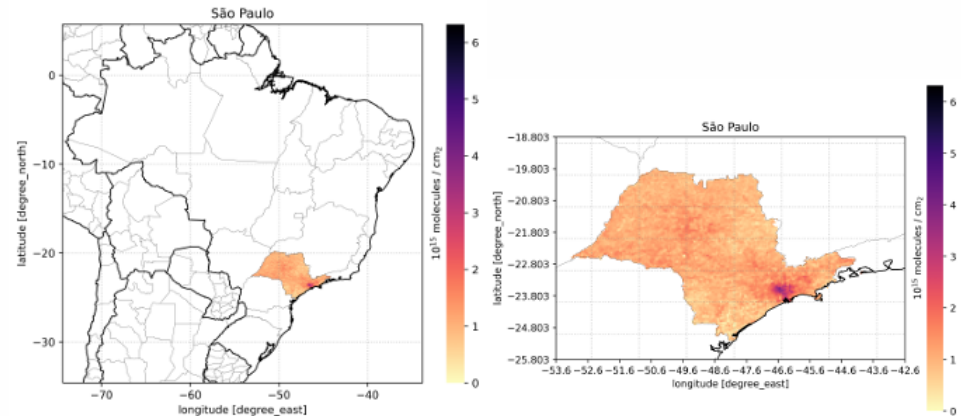


Figure: Segmented data using polygonal masks

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Experiments / Granularity: Country

The used cartographic database provides information for two levels of granularity, country and states.

Generate the graphical model of pollution for the smallest level of granularity, Brazil.

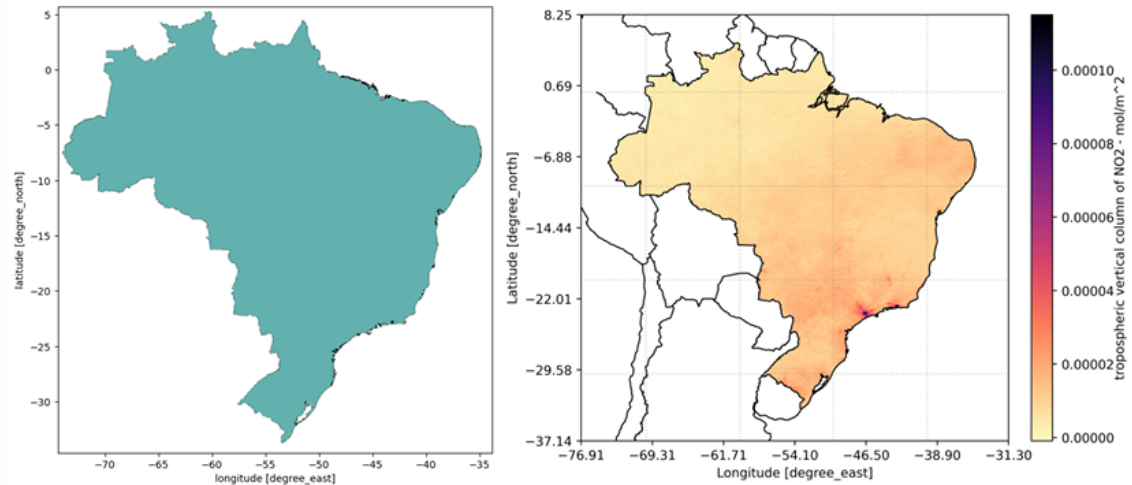
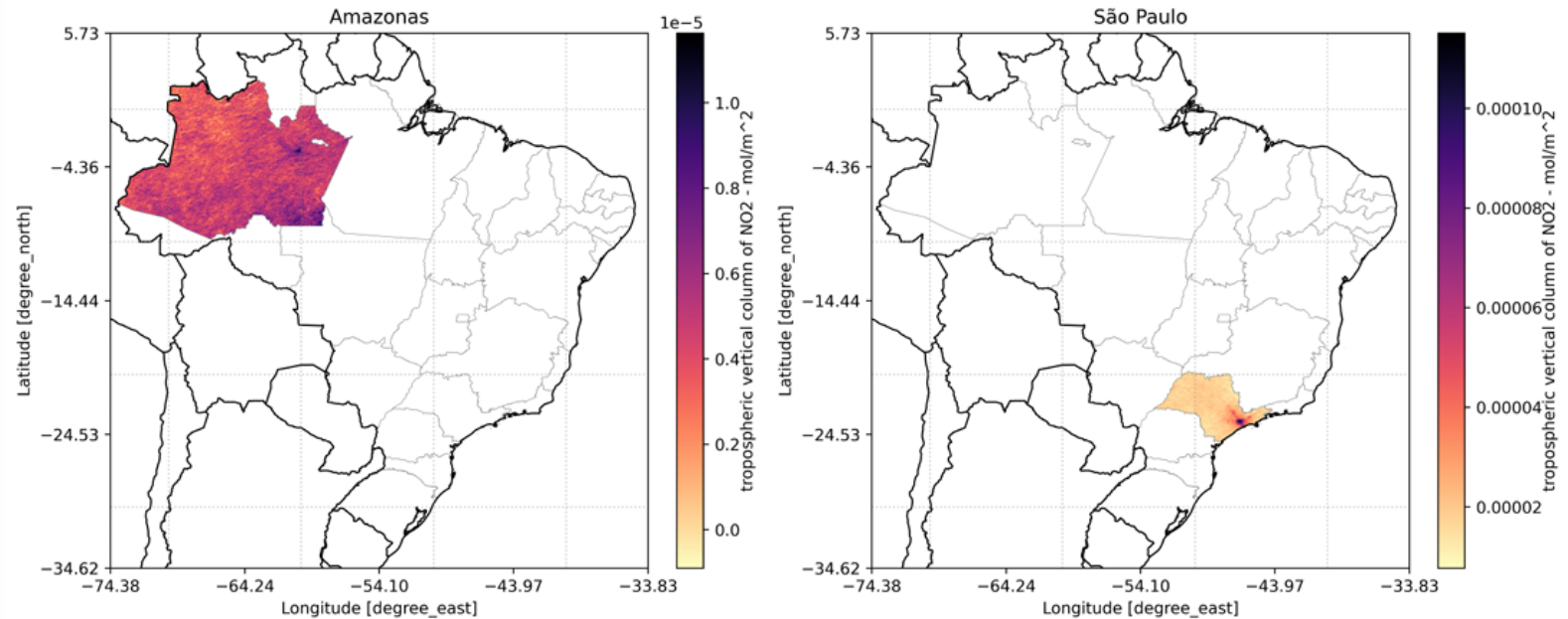


Figure: NO₂ measurements at the smallest level of granularity

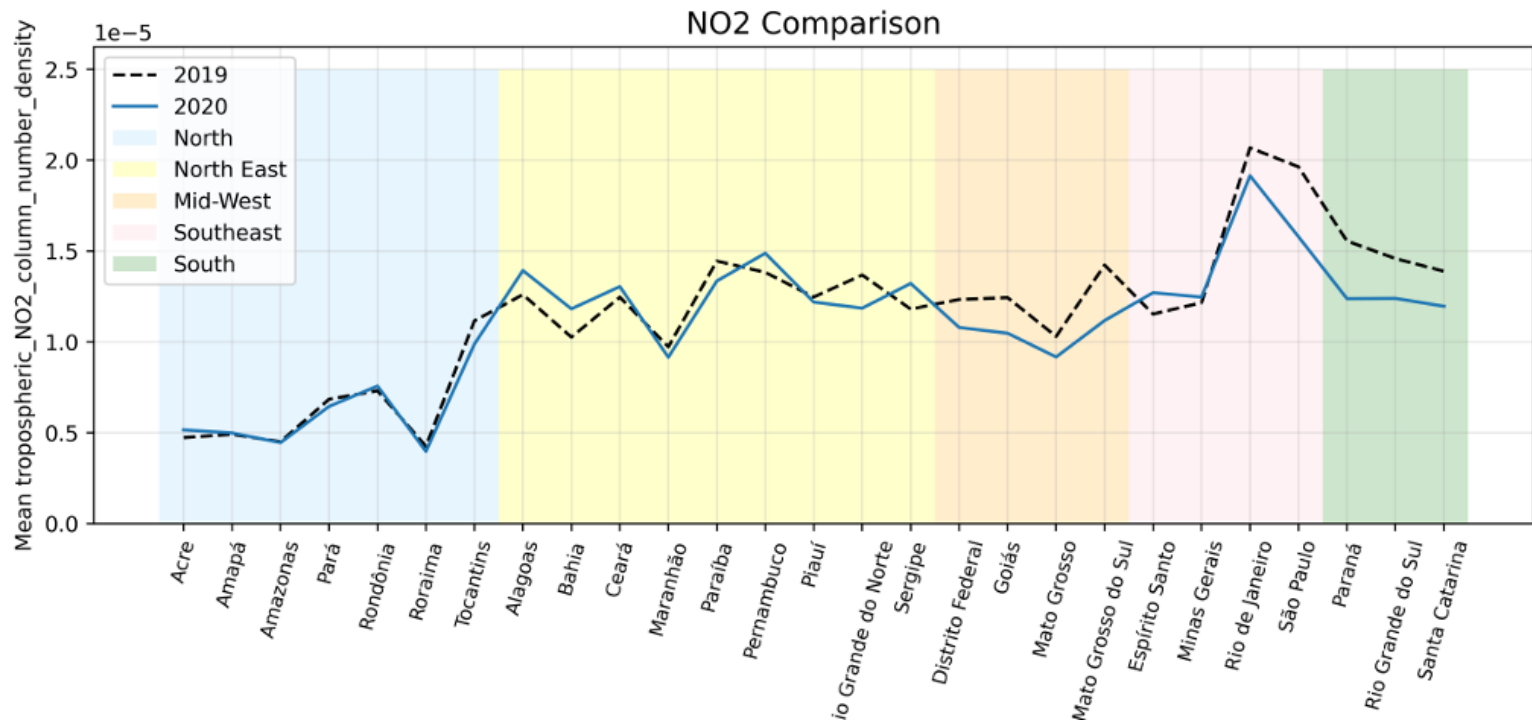
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Experiments / Granularity: States



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Experiments / Granularity: States



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Experiments - Comparison

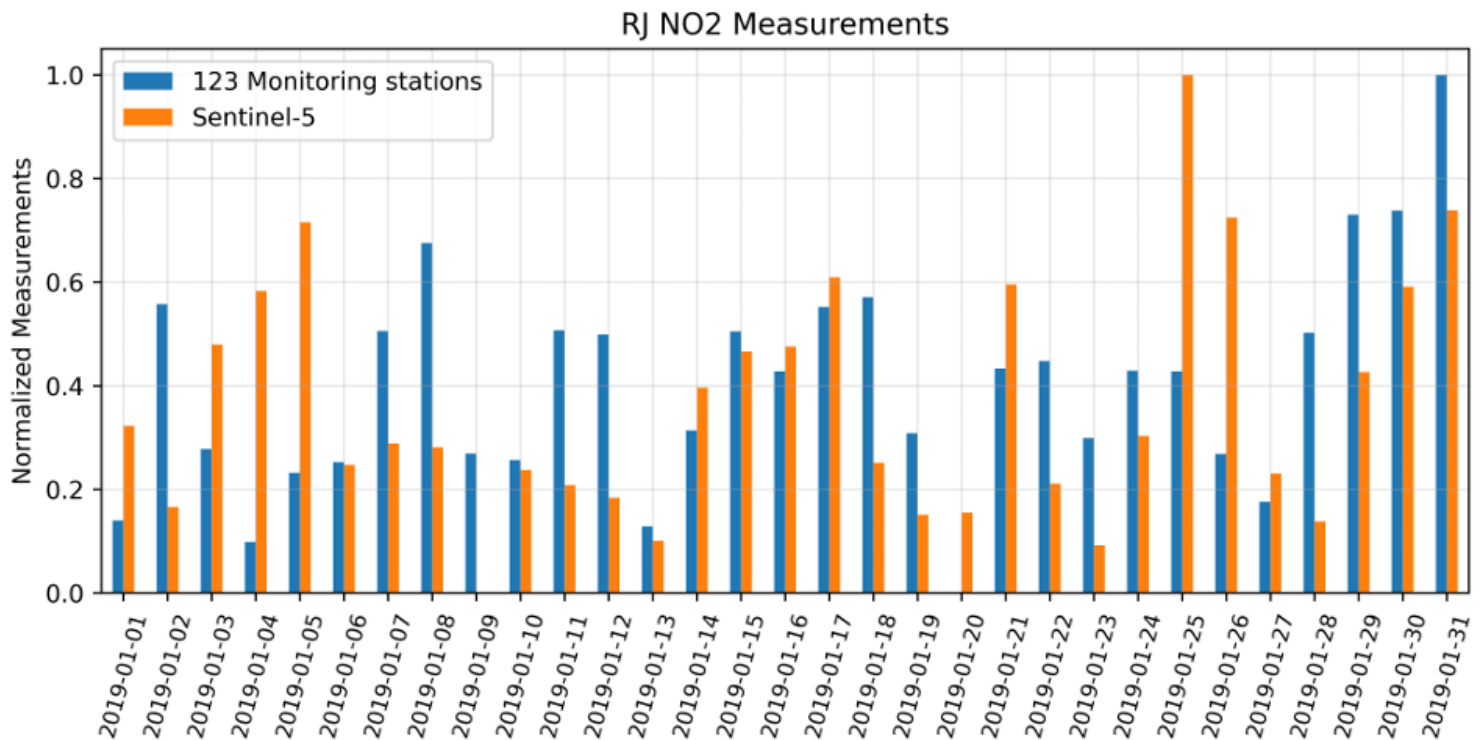
Considering the same time interval, four pollutants are found in common in eight states of Brazil.

Table: Common air pollutants in brazilian states.

Product	Pollutant	States available by IEMA
CO	Carbon Monoxide	Ceará, Espírito Santo, Minas Gerais, Pernambuco, Paraná, Rio de Janeiro, Rio Grande do Sul, São Paulo
NO ₂	Nitrogen Dioxide	
O ₃	Ozone	
SO ₂	Sulfur Dioxide	

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Experiments - Comparison / Rio de Janeiro



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Experiments - Correlation

Table: Correlation values between IEMA and Sentinel-5 data.

State	Pollutant	Pearson	PValue	Spearman	PValue
Ceará	NO ₂	0.266293	0.208469	0.038260	0.859117
Espírito Santo	NO ₂	-0.133553	0.473833	-0.076612	0.682072
Minas Gerais	NO ₂	0.075488	0.686502	0.072177	0.699603
Pernambuco	NO ₂	-0.179713	0.333349	-0.255645	0.165115
Paraná	NO ₂	0.382073	0.033913	0.439516	0.013363
Rio de Janeiro	NO ₂	0.255007	0.166208	0.187903	0.311413
Rio Grande do Sul	NO ₂	0.281729	0.124677	0.400403	0.025611
São Paulo	NO ₂	0.413269	0.020843	0.396774	0.027107

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Conclusions

- The data provided by Sentinel-5 are undoubtedly a significant advance in technology, constant monitoring allows generating pollutant levels and air quality index.
- The use of a polygonal masks is critical factor in obtaining reliable measurements representing the study areas. Without these polygonal masks, measurements would be made on geometric cutouts such as squares, where neighboring pollution could influence the measurements.
- Our proposed tool is robust and reliable in processing large volumes of data, flexible enough to be scaled or incorporated into other processes.

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Contribution

Current Contributions

- Dataset containing pollutant indices
- Visual representations of pollutant indices (granularity)
- Robust and efficient tool developed in python, encapsulated as a library.

Future Studies

- Methods of improvement of the resolution (spatial interpolation, AI)
- Methods for forecasting pollution (time series, statistical modeling techniques, machine learning)

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Thank you!

¡Gracias!

Obrigada!

Merci!

Aguyje!

Grazie!

Riqsikuyki!

谢谢你！

Questions?

¿Preguntas?

Perguntas?

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