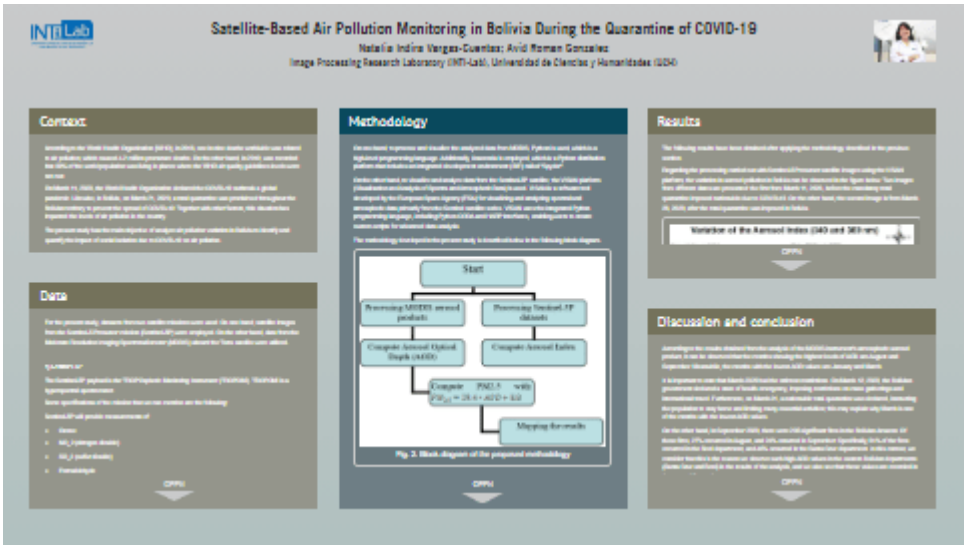
Satellite-Based Air Pollution Monitoring in Bolivia During the Quarantine of COVID-19



Natalia Indira Vargas-Cuentas; Avid Roman Gonzalez

Image Processing Research Laboratory (INTI-Lab), Universidad de Ciencias y Humanidades (UCH)

PRESENTED AT:

CONTEXT

According to the World Health Organization (WHO), in 2016, one in nine deaths worldwide was related to air pollution, which caused 4.2 million premature deaths. On the other hand, in 2019, was recorded that 99% of the world population was living in places where the WHO air quality guidelines levels were not met.

On March 11, 2020, the World Health Organization declared the COVID-19 outbreak a global pandemic. Likewise, in Bolivia, on March 21, 2020, a total quarantine was proclaimed throughout the Bolivian territory to prevent the spread of COVID-19. Together with other factors, this situation has impacted the levels of air pollution in the country.

The present study has the main objective of analyze air pollution variation in Bolivia to identify and quantify the impact of social isolation due to COVID-19 on air pollution.

DATA

For the present study, datasets from two satellite missions were used. On one hand, satellite images from the Sentinel-5 Precursor mission (Sentinel-5P) were employed. On the other hand, data from the Moderate Resolution Imaging Spectroradiometer (MODIS) aboard the Terra satellite were utilized.

1) Sentinel-5P

The Sentinel-5P payload is the TROPOspheric Monitoring Instrument (TROPOMI). TROPOMI is a hyperspectral spectrometer.

Some specifications of the mission that we can mention are the following:

Sentinel-5P will provide measurements of:

- Ozone
- NO_2 (nitrogen dioxide)
- SO_2 (sulfur dioxide)
- Formaldehyde
- Aerosol
- Carbonmonoxide
- Methane
- Clouds

Mission Orbit:

- Orbit Type: Sun-synchronous, polar
- Orbit Height: 824 km

Level 2 aerosol measurement products (L2__AER_AI) were used for the present study.

2) MODIS

The Moderate Resolution Imaging Spectroradiometer (MODIS) is an advanced remote sensing instrument aboard two satellites: Terra and Aqua. The Terra and Aqua satellites are part of NASA's Earth Observation System (EOS) program, launched in 1999 and 2002.

The MODIS instrument offers variable spatial resolution ranging from 250 meters to 1 kilometer. It can measure 36 different spectral bands with wavelengths from 0.405 µm to 14.385 µm.

Furthermore, it has a temporal resolution that provides global coverage every one to two days and a radiometric resolution of 12 bits.

The present study uses the atmospheric aerosol product from the MODIS instrument aboard the Terra satellite. The Level 2 product (MOD04_L2) is utilized; specifically, this product for measuring the optical thickness of ambient aerosols is only available at two spatial resolutions: 10 km and 3 km. The product with a spatial resolution of 3 km (MOD04_3K) available in Collection 6.1 will be used for the present study.

3) COVID-19 cases

In the case of Bolivia, as the COVID-19 pandemic spread globally, the Bolivian government declared a state of health emergency on March 12, 2020. As a result, restrictions on international travel were imposed, and mass gatherings were suspended. Subsequently, on March 21, 2020, Bolivia announced a nationwide mandatory quarantine, instructing the population to stay at home and limiting essential activities. However, despite the measures taken, the following figure illustrates the evolution of COVID-19 cases in Bolivia until the end of April 2020.

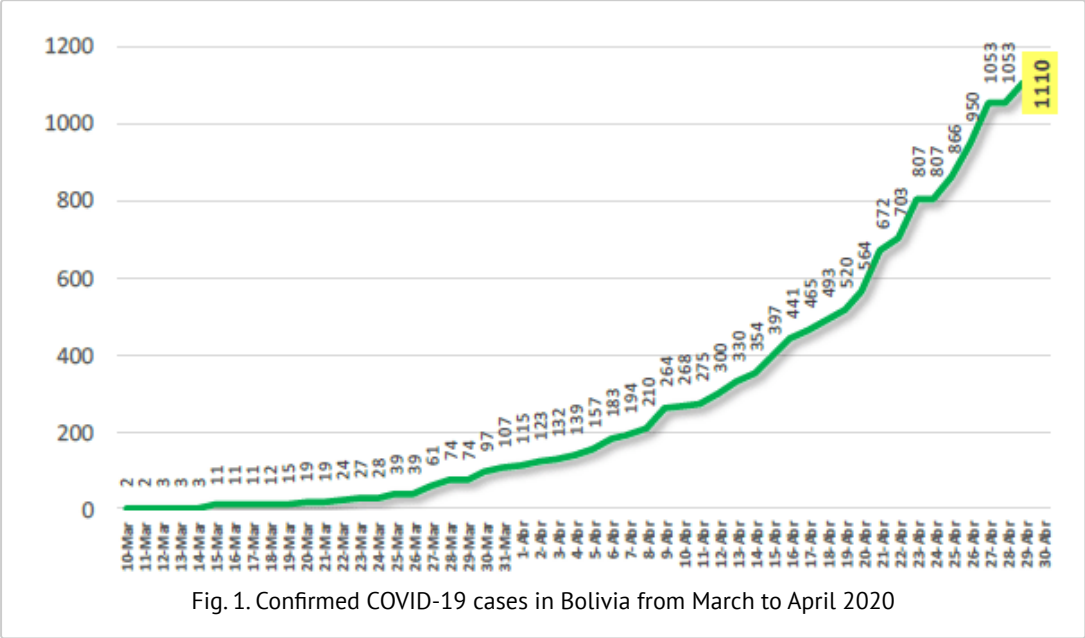


Fig. 1. Confirmed COVID-19 cases in Bolivia from March to April 2020

In the previous figure (Fig. 1), it was observed that from March 10 to April 30, 2020, Bolivia recorded 1,110 confirmed cases of COVID-19.

METHODOLOGY

On one hand, to process and visualize the analyzed data from MODIS, Python is used, which is a high-level programming language. Additionally, Anaconda is employed, which is a Python distribution platform that includes an integrated development environment (IDE) called "Spyder".

On the other hand, to visualize and analyze data from the Sentinel-5P satellite, the VISAN platform (Visualisation and Analysis of Spectra and Atmospheric Data) is used. VISAN is a software tool developed by the European Space Agency (ESA) for visualizing and analyzing spectral and atmospheric data primarily from the Sentinel satellite series. VISAN uses the integrated Python programming language, including Python CODA and HARP interfaces, enabling users to create custom scripts for advanced data analysis.

The methodology developed in the present study is described below in the following block diagram.

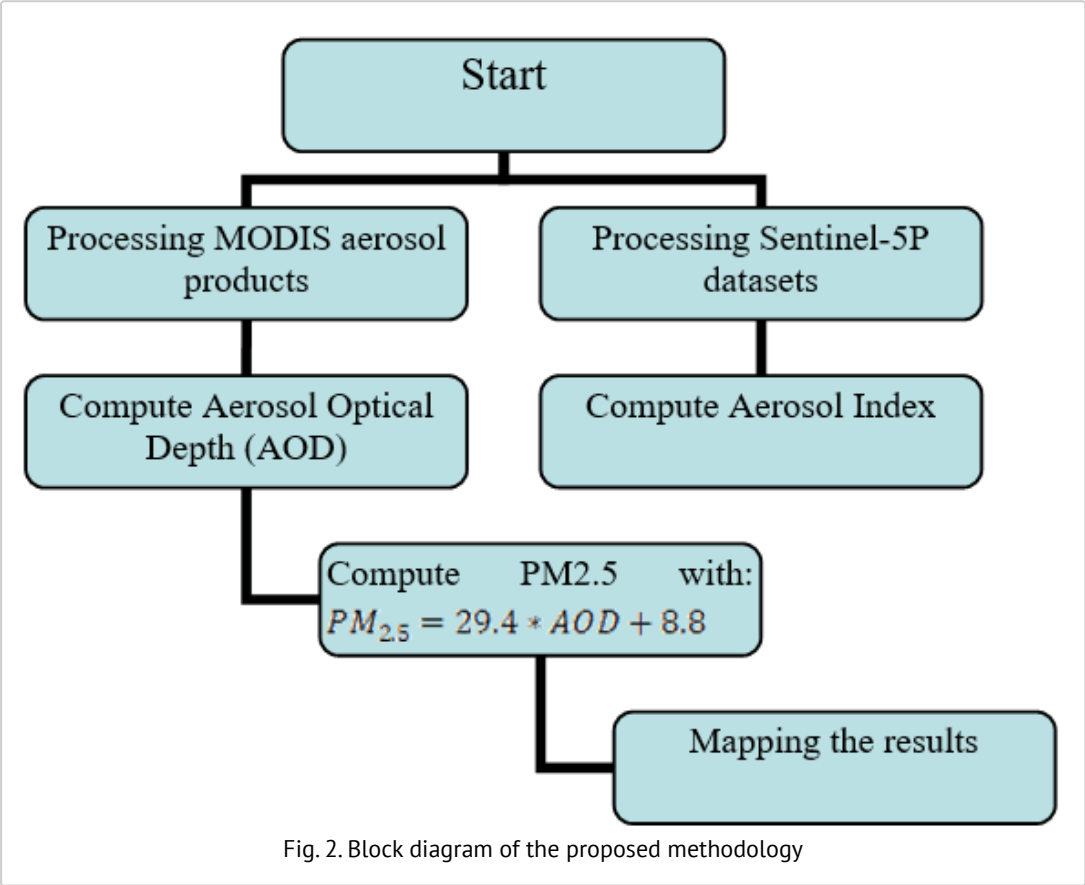


Fig. 2. Block diagram of the proposed methodology

The algorithm's primary function is to load the MOD04 product and identify the Science Data Sets (SDSs) for Optical_Depth_Land_And_Ocean within the product to calculate the Aerosol Optical Depth (AOD). Subsequently, the methodology calculates PM2.5 concentrations in the study area. On the other hand, the Aerosol Index will be calculated from the Sentinel-5P dataset using the VISAN tool. Finally, both results will be mapped to observe aerosol variations on different dates in 2020 within our area of interest.

RESULTS

The following results have been obtained after applying the methodology described in the previous section.

Regarding the processing carried out with Sentinel-5 Precursor satellite images using the VISAN platform, the variation in aerosol pollution in Bolivia can be observed in the figure below. Two images from different dates are presented: the first from March 11, 2020, before the mandatory total quarantine imposed nationwide due to COVID-19. On the other hand, the second image is from March 26, 2020, after the total quarantine was imposed in Bolivia.

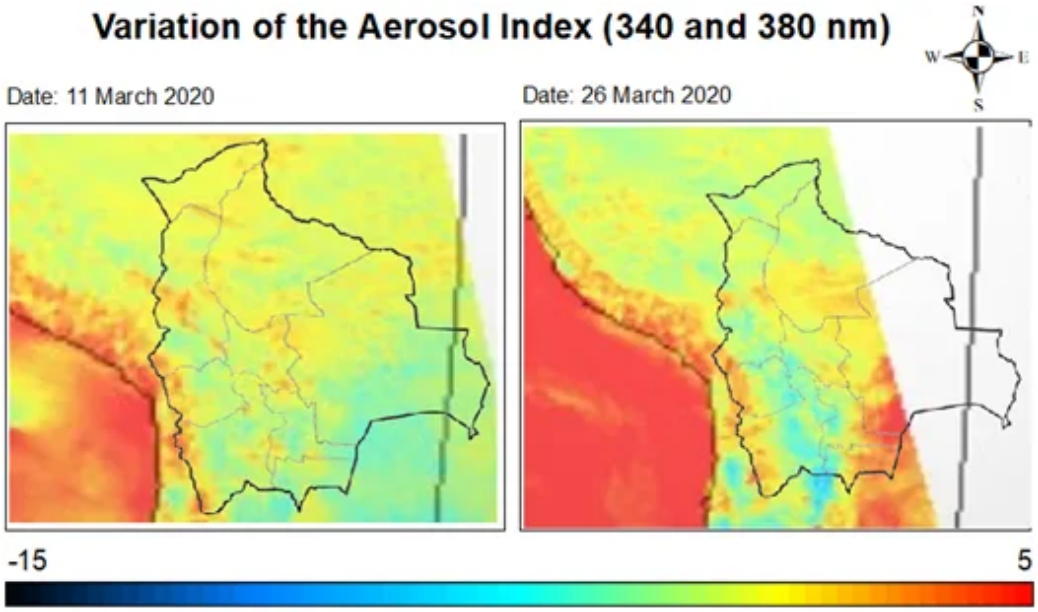


Fig. 3. Variation of the Aerosol Index in Bolivia, March 2020

As observed in Fig. 3, areas in red indicate higher aerosol presence, while blue areas represent lower aerosol presence. Thus, in the image from March 11, prior to the state of emergency declaration in Bolivia, predominantly yellow areas are observed, indicating a moderate aerosol presence. Meanwhile, in the image from March 26, a few days after the declaration of total quarantine in Bolivia, there is a prevalence of cyan areas, indicating minimal aerosol presence, and some orangish areas with moderate aerosol presence, particularly in the Santa Cruz department.

On the other hand, concerning the processing conducted with the atmospheric aerosol product of the MODIS instrument, the MODIS Aerosol Optical Depth in Bolivia on different dates in 2020 can be observed in the following figure.

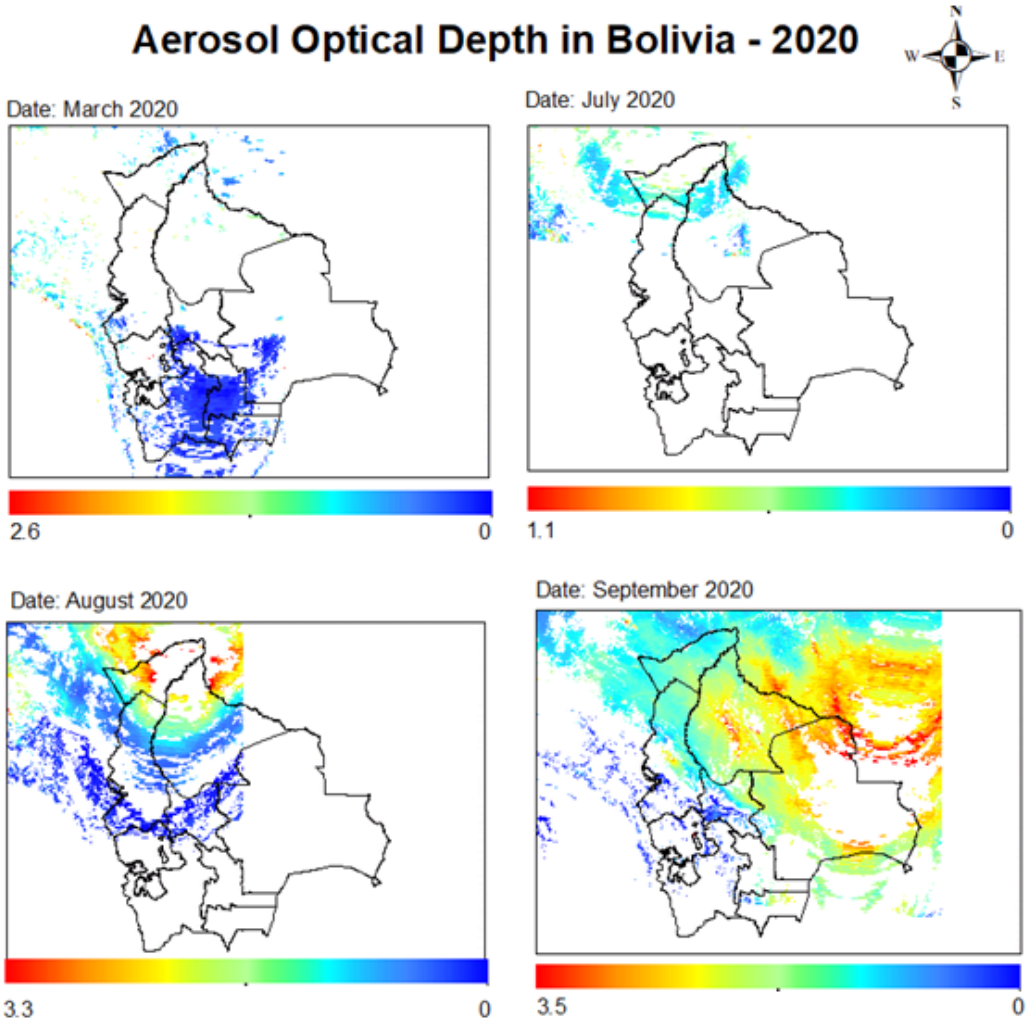


Fig. 4. Aerosol Optical Depth in Bolivia, 2020

As seen in Fig. 4, images from four specific months were analyzed. The criterion for selecting these particular dates was to have a dataset with cloud coverage of less than 15% in the study area to accurately measure the aerosols in the atmosphere. It is important to note that higher levels of AOD in Bolivia are represented in red, while lower levels are represented in blue.

Additionally, PM 2.5 values for the four months analyzed in 2020 were obtained, and the following air quality categorization results are observed in the region of interest.

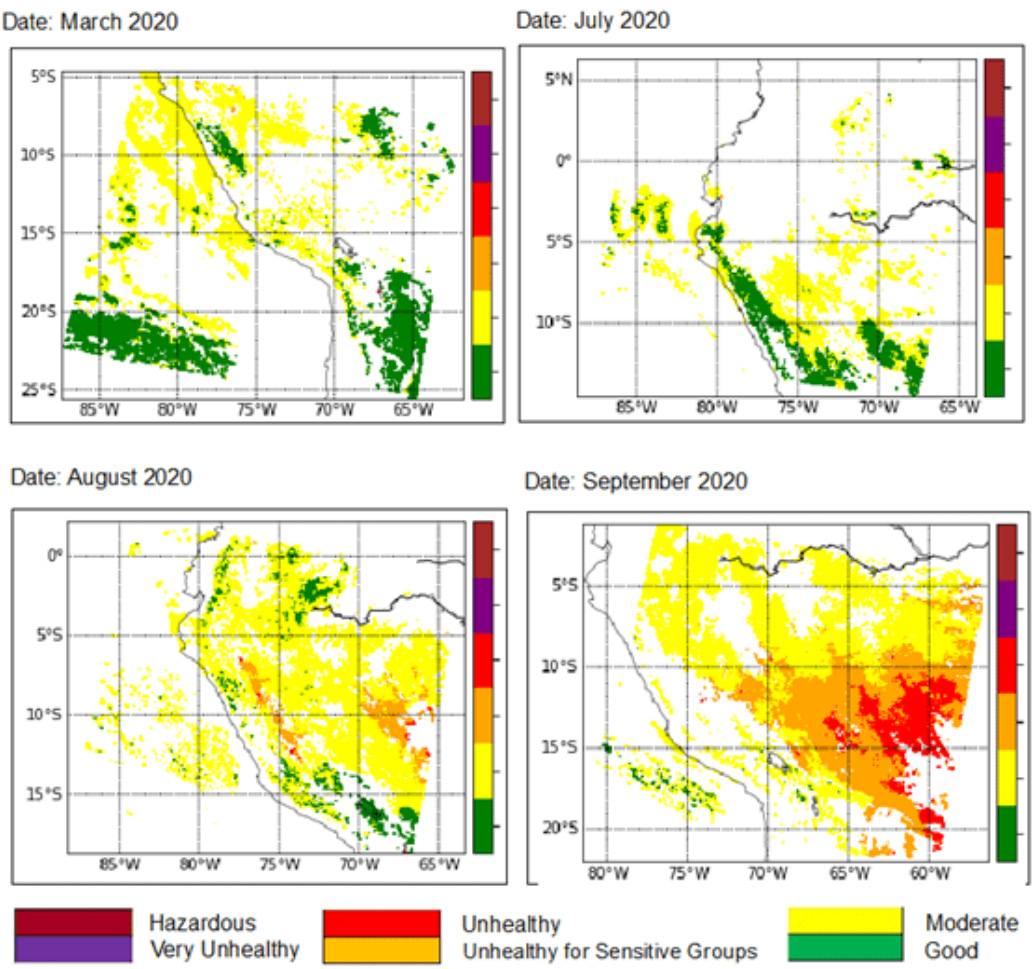


Fig. 5. Particulate Matter 2.5 (PM2.5) in Bolivia, 2020

As Fig. 5 shows, March and July primarily exhibit values categorized as "good," represented by the color green, and "moderate," indicated in yellow. However, in August, one can observe the presence of values categorized as "unhealthy for sensitive groups" represented by orange. Finally, in September, one observed values categorized as "unhealthy for sensitive groups", represented in orange and values classified as "unhealthy," represented in red.

DISCUSSION AND CONCLUSION

According to the results obtained from the analysis of the MODIS instrument's atmospheric aerosol product, it can be observed that the months showing the highest levels of AOD are August and September. Meanwhile, the months with the lowest AOD values are January and March.

It is important to note that March 2020 had the strictest restrictions. On March 12, 2020, the Bolivian government declared a state of health emergency, imposing restrictions on mass gatherings and international travel. Furthermore, on March 21, a nationwide total quarantine was declared, instructing the population to stay home and limiting many essential activities; this may explain why March is one of the months with the lowest AOD values.

On the other hand, in September 2020, there were 205 significant fires in the Bolivian Amazon. Of these fires, 27% occurred in August, and 24% occurred in September. Specifically, 51% of the fires occurred in the Beni department, and 46% occurred in the Santa Cruz department. In this context, we consider that this is the reason we observe such high AOD values in the eastern Bolivian departments (Santa Cruz and Beni) in the results of the analysis, and we also see that these values are recorded in August and September.

It can be observed that images from two satellite missions, in this case, the Terra satellite and Sentinel-5P, have been valuable for identifying aerosols in the study area, which is Bolivia. As a result of the analysis, it was noted that there was a decrease in aerosol values in the country after the decree of total immobilization was enacted on March 21, 2020.

Furthermore, it was observed that in March and July 2020, PM 2.5 concentrations were classified as "good" and "moderate." However, in August and September 2020, concentrations were classified as "unhealthy for sensitive groups" and "unhealthy." It was possible to identify that this was due to unfortunate forest fires occurring in the Beni and Santa Cruz departments during these months, illustrating the relevance of this type of analysis in quantifying the impacts of forest fires, not only in terms of vegetation but also in terms of air quality in the affected area.

As a future task, it is proposed to conduct a more extensive analysis for the year 2020 and subsequent years when the pandemic situation persisted, this would allow for the observation of aerosol variations over time.

Acknowledgements

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TRANSCRIPT