Evaluation of Air Pollution of NO2 over Armenia and Belarus

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***Abstract*—Over time, the population and anthropogenic activities increase, adversely affecting our atmosphere. In particular, an increase in air temperature leads to a change in the number of various gases that fill our atmosphere, the growth and decrease of which can significantly affect our environment. That is why air quality evaluation and prediction have become an important research area. Earth Observations (EO) provide robust monitoring to address environmental challenges using satellite and in-situ data. The study aims to evaluate nitrogen dioxide (NO_2) air pollutants for both territories Armenia and Belarus using the SENTINEL 5P Tropospheric Monitoring Instrument (TROPOMI) remote sensing platform and ground-based measurements during Sep 2018 - Aug 2019 considering the synaptic conditions and data availability. The SENTINEL 5P datasets of NO_2 during 2018-2019 have been used for the studies obtained from the Google Earth Engine (GEE). The studies show that NO_2 excesses in their troposphere for the regions of Armenia and Belarus. This increase is correlated with the rise in urban population, causing dramatic adverse effects on the atmosphere. Compared to traditional methods, the study may substantially increase the government's and policymakers' capability to take timely action on anthropogenic activities in the mentioned cities to mitigate the emission of NO_2.**

***Keywords*— Earth observation, SENTINEL 5P, Armenia, Belarus, air pollution, NO_2**

I. Introduction

The air pollution concentration varies spatially and temporarily, causing air pollution patterns to change at different locations and times due to changes in meteorological and topographical conditions [1]. The primary sources of air pollutants include vehicles, industries, domestic activities, and natural emissions. The elevated levels of air pollutants in the atmosphere have detrimental effects on both human health and property. Consequently, the environment plays a crucial role in ensuring the well-being of Earth's inhabitants. Therefore, it is essential to observe and monitor the Earth for anomalies. Major air pollutants comprise carbon monoxide (CO), carbon dioxide (CO_2), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), ozone (O_3), and particulate matter (PM) [2]. A pollutant that can severely affect living things' health is NO_2, a red-brown acidic gas [3]. It is critical to monitor and reduce air pollution, mitigating its impacts on human health and the environment. EO satellite and in-situ data [4] provide robust monitoring mechanisms for environmental problems due to geospatial consistency, accessibility, repeatability, and global coverage. EO supports data aggregation by offering policymakers repeatable, continuous, and multi-annual quantitative and qualitative data. Satellite technology is vital for monitoring national, regional, continental, and global air quality [5]. Air pollution has reached a critical value in Armenia and Belarus, impacted by industrial and other anthropogenic activities.

According to the analysis, the concentrations of the studied pollutants in Belarus are generally low compared to Armenia. However, there are local hot spots where pollution levels can be much higher, exceeding the standard specified by the World Health Organization. The energy and transport industries and the natural sources are the primary industrializations and growing population factors. The growing energy demand has made burning hydrocarbons the primary source of anthropogenic atmospheric pollution. Transport is still the most significant contributor to air pollution.

In the atmospheric air monitoring system in the Republic of Belarus, observations are made on the content of pollutants in the atmospheric air, precipitation, and snow cover. The state atmospheric air monitoring network includes 67 observation points. There are 12 observation points in Minsk; in Mogilev - 6, Gomel and Vitebsk - 5 each, Brest, Grodno - 4 observation points each; in other industrial centers - from 1 to 3 observation points. In the cities of Minsk, Vitebsk, Mogilev, Grodno, Brest, Gomel, Polotsk, Novopolotsk, and Soligorsk, in the area of the Mozyr industrial hub and at the background monitoring station of the Berezinsky Reserve, 16 automatic stations operate in the normal mode, allowing to obtain information on the content of priority pollutants in the air real-time mode [6].

The national air quality monitoring network of Armenia consists of 15 stations, 5 of which are located in the capital Yerevan, measuring SO_2, CO, NO_2, O_3, and PM, the most significant air pollutants encountered in our daily life. High concentrations of these pollutants near the Earth's surface can cause serious health problems. The remote sensing data is collected in the Armenian Data Cube, a complete and up-to-date archive of EO data (e.g., Landsat, Sentinel) [7].

In Armenia and Belarus, air pollution studies have been carried out mainly using ground-based data for contamination monitoring limited to the measuring stations' location by weakly addressing the issue. Recently, satellite remote sensing of tropospheric NO_2 has been effectively used to study the spatial patterns of NO2 at local, regional, and global scales [8]–[10]. As the first of the Sentinel 5P, it provides accurate validation versus independent ground-based measurements. The high-resolution S5-P TROPOMI imagery with the temporal and spatial extent enables analyzing and mapping air pollution in Armenia's different parts. Until now, the coherence analysis of Sentinel-5P TROPOMI's NO_2 data and surface monitoring data has still not been carried out, so it is helpful to carry out a coherence analysis of NO_2 air pollutants surface concentrations over Armenia and Belarus, particularly in Yerevan and Minsk. The study aims to estimate and analyze the NO_2 air pollutants surface concentrations over Armenia and Belarus, using high-resolution space-borne data over 12 months (Sep. 2018 – Aug. 2019).

II. Study area

The Republic of Armenia is located South of the Caucasus, at the junction of the Caucasus with Western Asia. It occupies a small part of the West Armenian Highlands. It borders Georgia and Azerbaijan in the North and East, West and Southeast, with Turkey and Iran. It is between latitude 38.51° to 41.18° North and longitude 43.29° to 46.37° East. The republic is landlocked. The Republic of Armenia covers an area of 29800 km^2, approximately equal to the territory of Belgium and Albania. The greatest length from Northwest to Southeast is 360 km, and from West to East - 200 km. Armenia is a mountainous country with an average elevation of 1800 meters. The tallest point is 4090 meters (Mount Aragats), and the lowest is 375 meters above sea level (Debed River). The territory is divided into ten regions: Aragatsotn, Ararat, Armavir, Gegharkunik, Lori, Kotayk, Shirak, Syunik, Tavush, Vayots Dzor, and the capital city Yerevan. Yerevan is the capital of Armenia, covering an area of 223 km^2, with coordinates 40.10°N, 44.30°E (see Fig.1), and is located in the Northeastern part of Ararat valley, on both banks of the Hrazdan River, on the altitude of 900-1200 m above sea level. According to the official estimate of 2018, the city's population is about one million and one hundred thousand.

In the past few years, the air quality in the country has been a cause of serious concern as the limit values set for protecting

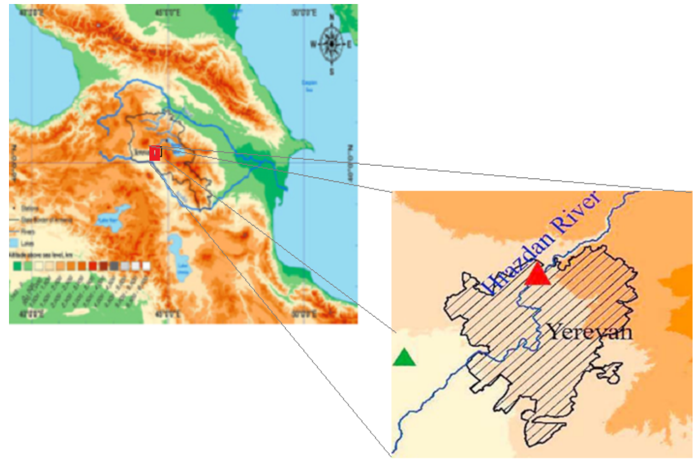


Fig. 1: Armenia on the world map and the physical map of Armenian Highland and Southern Caucasus region (the state border of Armenia is indicated with a black line)

human health are significantly exceeded. According to the Armenia Air Quality Assessment Report for 2019, air pollution is at a high level in the most significant urban settlements, especially in the city of Ararat, Hrazdan, Kadjaran, Alaverdi, where the NO_2, SO_2, and CO have exceeded the limit values of 40 $\mu g/m^3$ for NO_2 at annual, and 10 $\mu g/m^3$ at daily period [11].

According to the national atmospheric emission data, emission from mobile sources is about 57%, and from stationary sources 43%. About 73.1% of the total emitted harmful substances from mobile sources are carbon monoxide, 16.3% - volatile organic compounds, 10.4% - nitrogen oxides, and 0.2% - other substances. About 64.9% of the harmful emissions emitted from stationary sources are hydrocarbons, 25.1% - sulfur dioxide, 5.1% - powder, 2.8% - carbon monoxide, 1.6% - nitrogen oxides, and 0.5% - other materials. The Republic of Belarus is a landlocked country in Eastern Europe. It is bordered by Russia to the East and Northeast, Ukraine to the South, Poland to the West, and Lithuania and Latvia to the Northwest(see Fig. 2). Belarus is a medium-sized European state. The total area is 207,600 km^2 or about 2% of the total area of Europe. Belarus is the 13th largest country among 44 continental European states (the world's 84th largest country). The climate is halfway between the temperate and subarctic

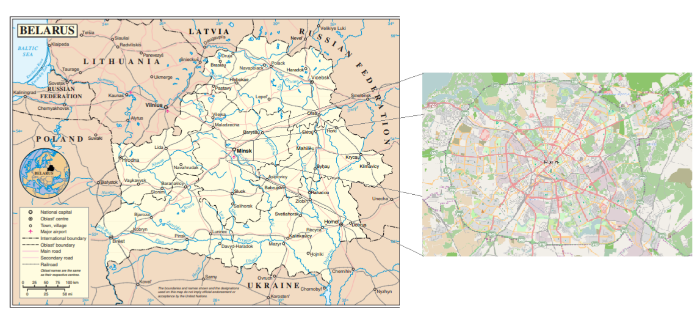


Fig. 2: Belarus on the map of Europe with country borders

zones. It is administratively divided into seven regions named after the cities that serve as the administrative centers: Brest, Gomel, Grodno, Mogilev, Minsk, and Vitebsk. Minsk is the capital and the largest city.

The surface concentration measured in μg/m^3 is available on a time slot of 1 h. From these data, hourly values have been extracted, and daily/monthly averages have been computed as well, for comparison with consistent satellite observations. At the same time, the TROPOMI level-2 data is reported in the International System of Units, which means in mol/m^2.

III. Materials and Methods

This research obtains satellite images from the Copernicus program of the European Union, specifically Sentinel-5 Precursor (Sentinel-5P) images from the Google Earth Engine data catalog.

The Sentinel-5p satellite was successfully launched on October 13, 2017, and the NO_2 data were released on July 10, 2018. GEE is an open-source tool and is a cloud-based platform for planetary-scale geospatial analysis that brings Google's massive computational capabilities to bear on a variety of high-impact societal issues, including deforestation, drought, disaster, disease, food security, water management, climate monitoring, and environmental protection. Figure 3 shows a screenshot of the main windows of the GEE platform.

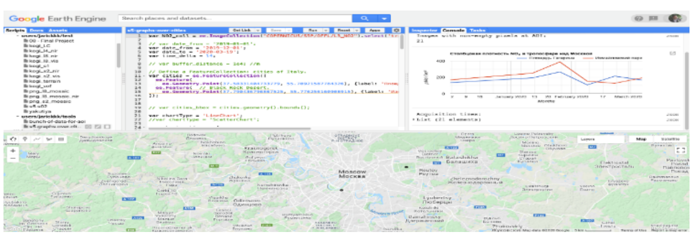


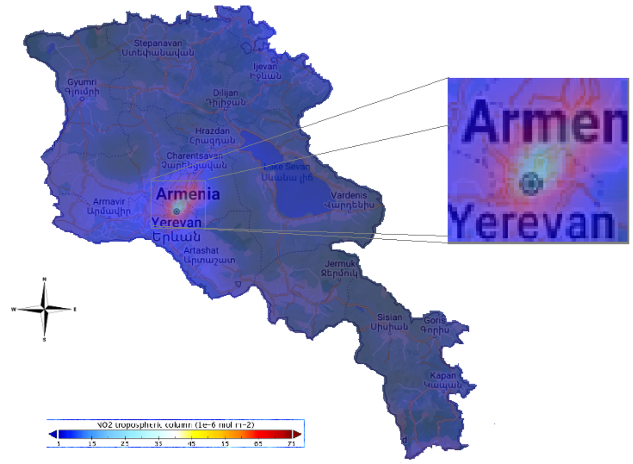
Fig. 3: The Earth Engine Code Editor

Thus, S5-P level 3 datasets are proposed in GEE to receive the average NO_2 values over Armenia and Belarus, then compared them with in-situ average NO_2 data in the same period inaccuracy comparison, the values of 15 stations located in Armenia and 64 stations located in Belarus have been considered. According to the images from Tropomi, it was revealed that in Armenia, the most polluted air is over Yerevan, and in Belarus - over Minsk, which corresponds to the reports from the observed stations.

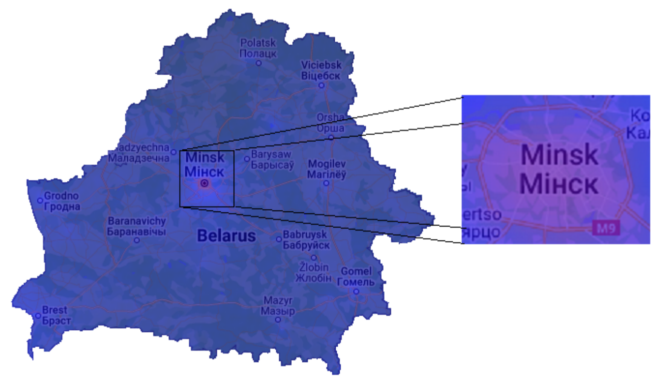
IV. Results and Discussions

Figure 3 shows average-wise S5-P NO_2 data retrieved from Sentinel 5-P from September 1, 2018, to August 30, 2019, and statistically processed. The NO_2 concentration is shown, for individual cities of Armenia, in different colors like "blue", "purple", "cyan", "green", "yellow", "and red". As the color becomes more reddish, that area will have excess NO_2.

The analyses show that the most polluted atmosphere in Yerevan corresponded to the average observational data from five stations located within the city from September 1, 2018, to August 30, 2019.



(a) Armenia and Yerevan city (highlighted area)



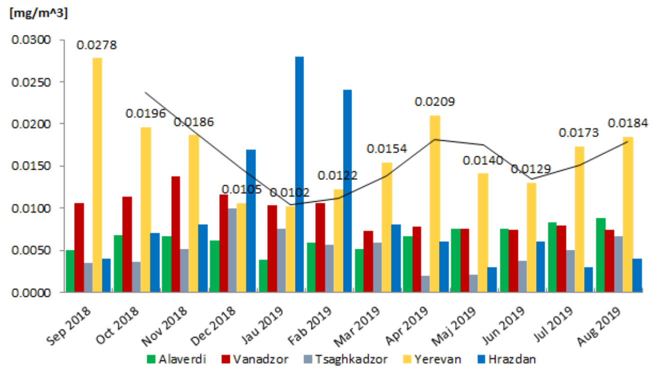
(b) Belarus and Minsk city (highlighted area)

Fig. 4: NO_2 data taken from the Sentinel-5P Tropomi over Armenia and Belarus

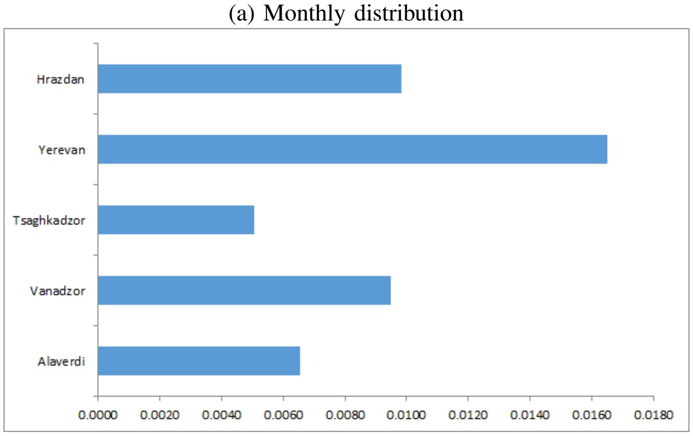
The Armenian air quality daily report has been used as the NO_2 surface monitoring concentration data source. Monthly averages of NO_2 concentrations at surface monitoring stations in Armenia (a total of 5 cities: Alaverdi, Hrazdan, Tcaghkadzor, Vanadzor, and Yerevan) were derived from daily data. Based on the measurement data from the listed stations, a diagram of the monthly distribution of NO_2 concentration and average values for the period under consideration from September 2018 to August 2019 (Fig. 4 a) and b), respectively) were obtained for five cities.

The average surface NO_2 level over Armenia for 12 months was 0.23*10^{-4} mol/m^2. The maximum value of NO_2 for the same period was observed in Yerevan, 0.65*10^{-4} mol/m^2. The excellent relationship we see for this study shows the relatively high homogeneity of the stations in Yerevan, Hrazdan, and Tsaghcadzor. In effect, they are within the bulk area(Fig. 3.a), which is affected by more intense and persistent air pollution concerning other regions in Armenia. However, the highest concentration of NO_2 is traced over the city of Yerevan.

In Belarus, the most polluted atmosphere is over Minsk. According to the analysis, the average concentration of NO_2



(a) Monthly distribution



(b) Average distribution

Fig. 5: Monthly and average distribution of NO_2 concentration, according to measurements of each of the five cities

in Belarus is relatively low, $0.24 * 10^{-4}$ mol/m^2. In general, the lowest concentrations of NO_2 are located in the north of Belarus. Several hotspots are significantly higher, including in the capital's urban area, Minsk, where NO_2 values exceed $0.50*10^{-4}$ mol/m^2 (more than double the average for the country).

Satellite image analysis shows that the S5P/TROPOMI can sense down to the surface, and satellite data can discriminate between low and high pollution loads.

V. Conclusion

In this study, the concentration of NO_2 in the Troposphere of Armenia and Belarus has been investigated, utilizing data from the Sentinel 5p satellite. We obtained valuable insights by processing temporal datasets from September 1, 2018, to August 30, 2019, in Google Earth Engine. The experiments revealed the overall distribution of NO2 concentration in the troposphere, as illustrated in Figure 3(a).

Building upon these findings, our future endeavors will focus on extending the available comprehensive scalable platform with new air pollution services [12]. This platform will integrate data from various sources, including archives of remote-sensing images and in-situ measurements. By harnessing the power of this integrated data, our objective is to enable accelerated multidimensional computations within a limited time frame and with minimal resource requirements. This platform will enhance our understanding of environmental dynamics and facilitate informed decision-making.

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