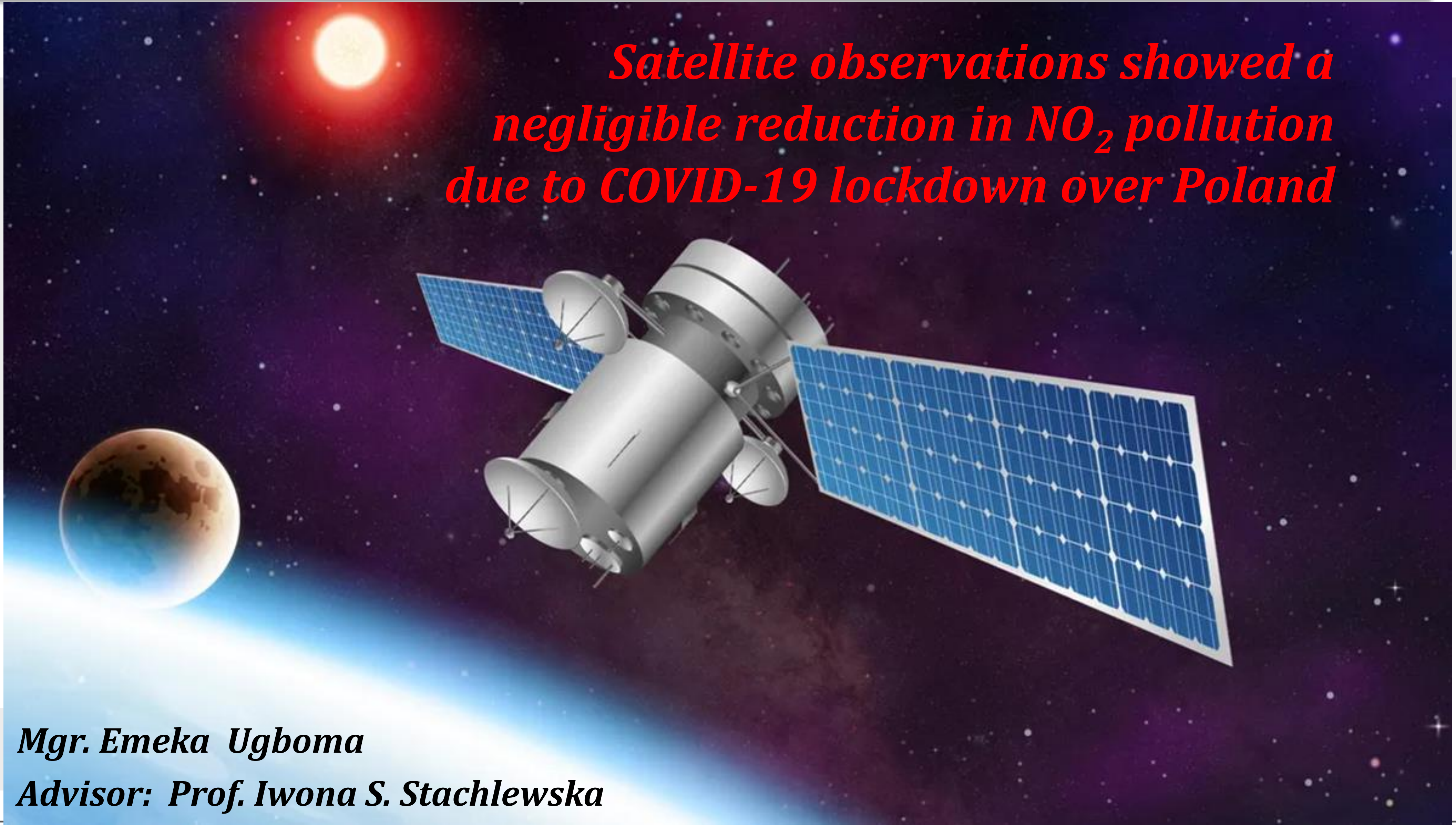
UNIWERSYTET WARSZAWSKI | INSTYTUT GEOFIZYKI
WYDZIAŁ FIZYKI

Satellite observations showed a negligible reduction in NO_2 pollution due to COVID-19 lockdown over Poland



Remote Sensing Laboratory

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Presentation plan

- Introduction
- Literature
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What is air pollution?

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https://www.theguardian.com/global-development/2020/jul/01/

https://www.gbaramatuvoicenews.com/port-harcourt-residents-cry-out-as-life-threatening-black-soot-resurfaces/

Does air pollution affect human lives and the environment?

Major air pollutants

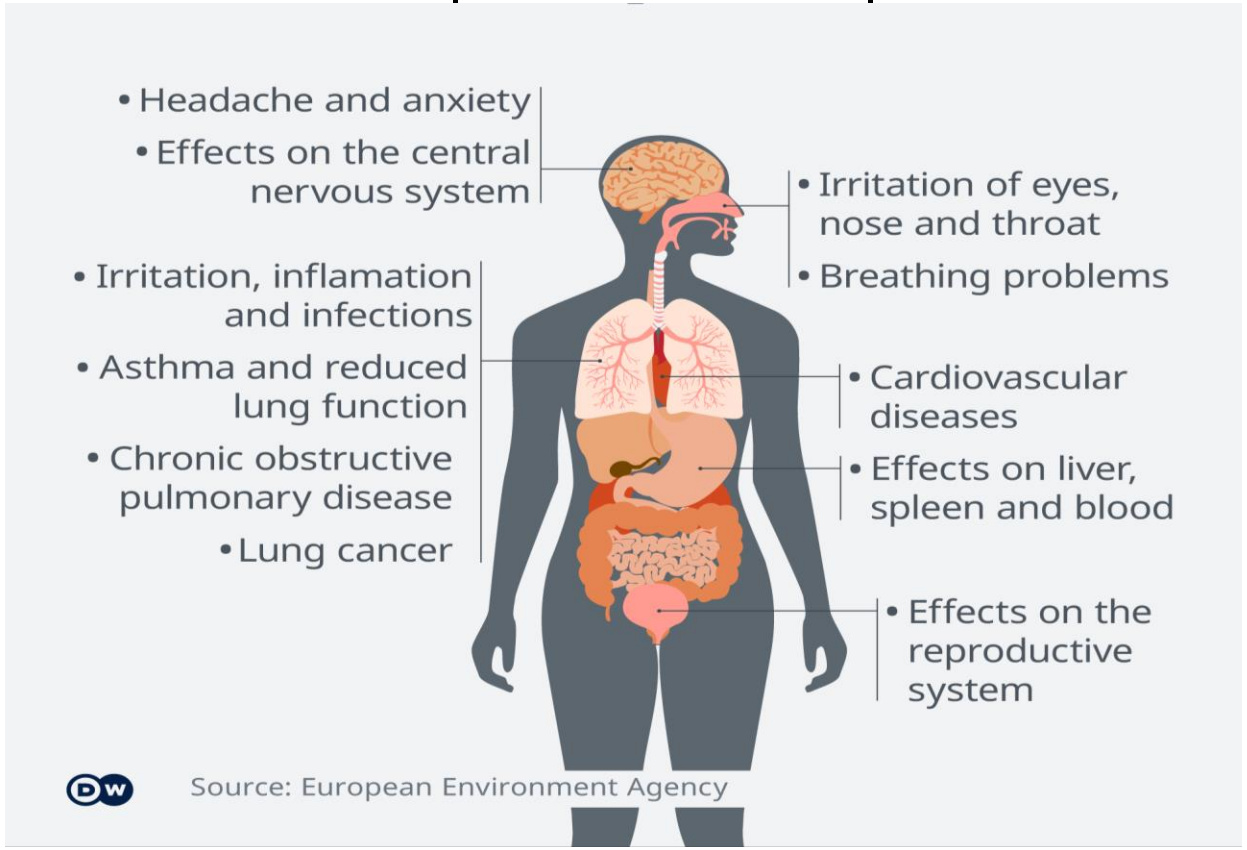
- Carbon dioxide
- Ozone
- Carbon monoxide
- **Nitrogen dioxide (NO_2)**
- **Nitrogen oxides (NO_x)**
- Methane (CH_4)
- Sulphur dioxide (SO_2)
- Formaldehyde (HCHO)
- Toxic compounds (eg. lead)
- Aerosols (anthropogenic and natural).

https://wiadomosci.radiozet.pl/Polska/Smog.-Zla-jakosc-powietrza-nad-Warszawa.-Przekroczono-stan-ostrzegawczy

Why is it important to monitor air pollution?

Monitoring air pollution is crucial for various reasons, as it helps us understand and address the environmental and public health impacts of polluted air.

- Health concerns
- Environmental impact
- Public awareness
- Regulatory compliance
- Risk assessment
- Urban planning
- Industrial safety
- Research purposes
- Emergency response, etc.



https://www.dw.com/en/health-groups-call-for-fossil-fuel-nonproliferation-treaty/a-63107797

Literature

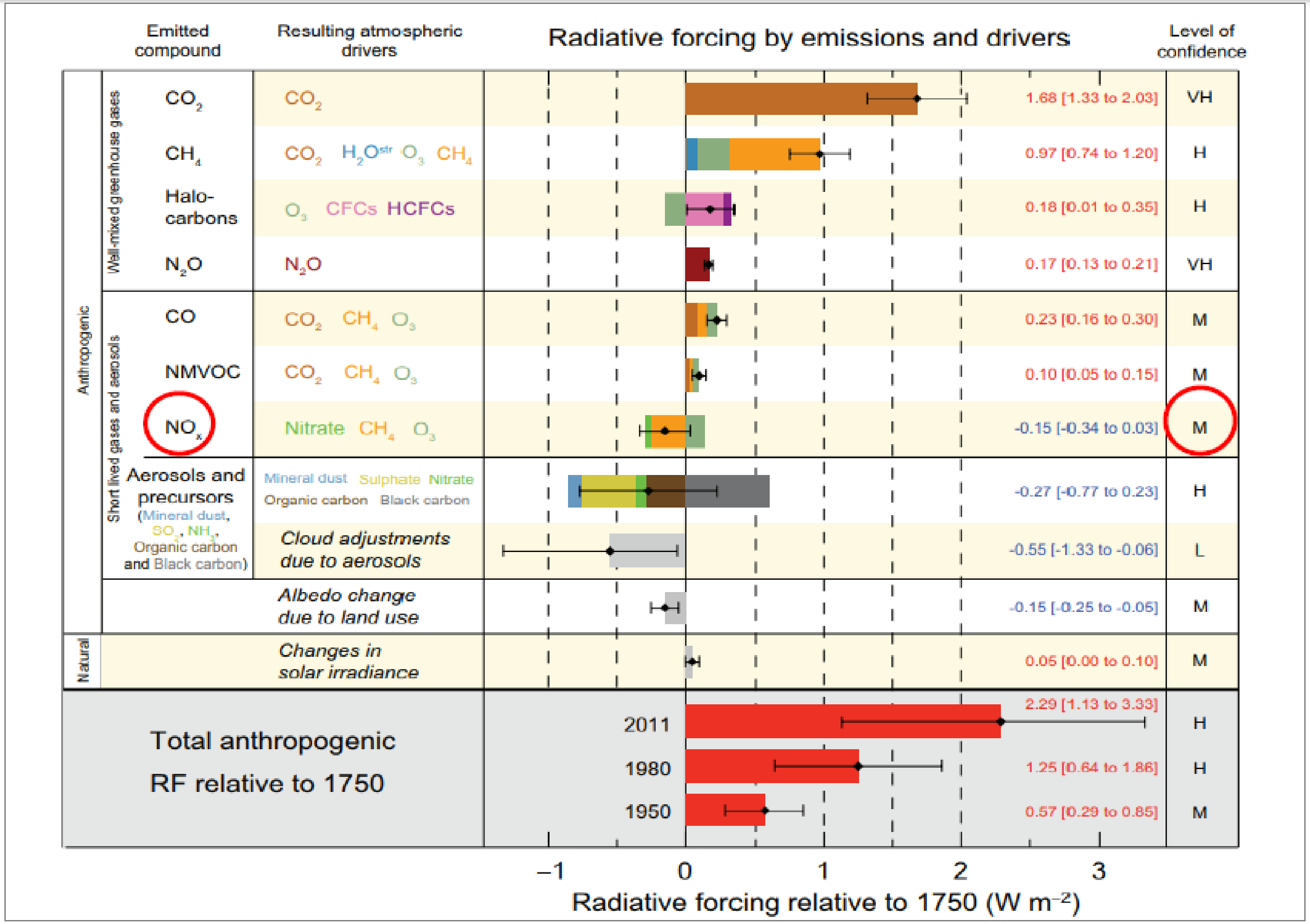
•Nitrogen dioxide (a part of $NO_x = NO + NO_2$) is a well-known cause of poor air quality in the world's most densely populated and industrialized places. Long-term atmospheric concentration exposure of NO_2 is hazardous to living beings.[1,2]

•The key European anthropogenic NO_x sources, according to the European Environment Agency[3], are **road transport** (39%) and **energy production and distribution** (16%); **commercial, residential, and household** (14%); **energy use in industry** (12%); **agriculture** (8%); **non-road transport** (8%); and **industrial processes and product use** (3%).

The key source of nitrogen dioxide resulting from human activities is the combustion of fossil fuels (coal, gas and oil) especially fuel used in cars. Natural sources of other nitrogen oxides include volcanoes and bacteria.

[1]Lelieveld et al., (2015). The contribution of outdoor air pollution sources to premature mortality on a global scale, Nature,525, 367–371.
[2]IPCC (2013): Summary for Policymakers. In: Climate Change 2013: The Physical Science Basis
[3]European Environmental Agency (EEA 2020) European Union emission inventory report 1990–2018 under the UNECE Convention on Long-range Transboundary Air Pollution (LRTAP), Copenhagen, Denmark.

Literature: The IPCC Report



IPCC (2013): Summary for Policymakers. In: Climate Change 2013: The Physical Science Basis

Literature

During the COVID-19 lockdown, there was:

- 6% decrease in NO_2 in Tehran, Iran (Sharifi and Felegari, 2022),
- 30%–39.79% drop in NO_2 in East China (Filonchyk et al., 2020; Fei et al.,2022),
- 40%–50% drop in Arabian Pennisula (Karumuri et al., 2022),
- 20%–40% reduction was recorded in India (Biswal et al.,2021),
- 9%–43% in the United States (Goldberg et al., 2020),
- 39% decrease in Greece (Koukouli et al., 2021),
- 23% drop was observed in Germany (Balamurugan et al., 2021),
- 50% reduction in Spain (Petetin et al., 2020),
- 67.7% drop in Rome, Italy (Bassani et al., 2021), and many more.

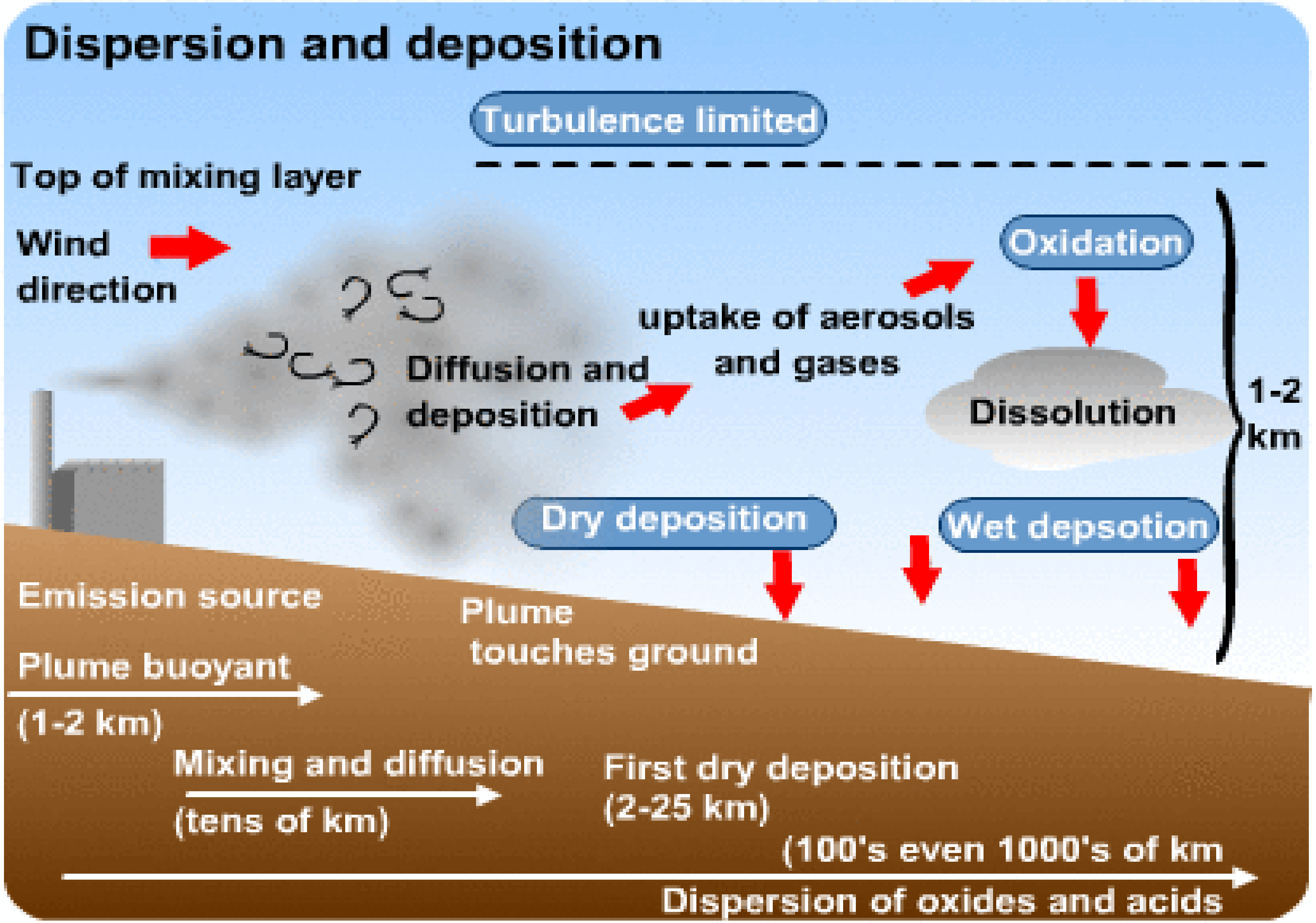
Literature

In Poland,

- 10% reduction of TROPOMI NO_2 in early spring by Grzybowski et al., 2021
- 10%–19% reduction of OMI NO_2 by Filonchyk et al., 2021
- Usefulness of NO_2 from OMI and SCIAMACHY for improvement of NO_x surface emission prediction by Szymankiewicz et al., 2021
- Annual variation of TROPOMI NO_2 and the selection of satellite scenes for monthly averages by Kawka et al., 2021

None of these studies attempted to assess the impact of the COVID-19 lockdown on air quality in Poland in terms of long-term variability of NO_2, for which longer datasets need to be used, such as OMI NO_2 for at least a decade.

Atmospheric processes



Study Area

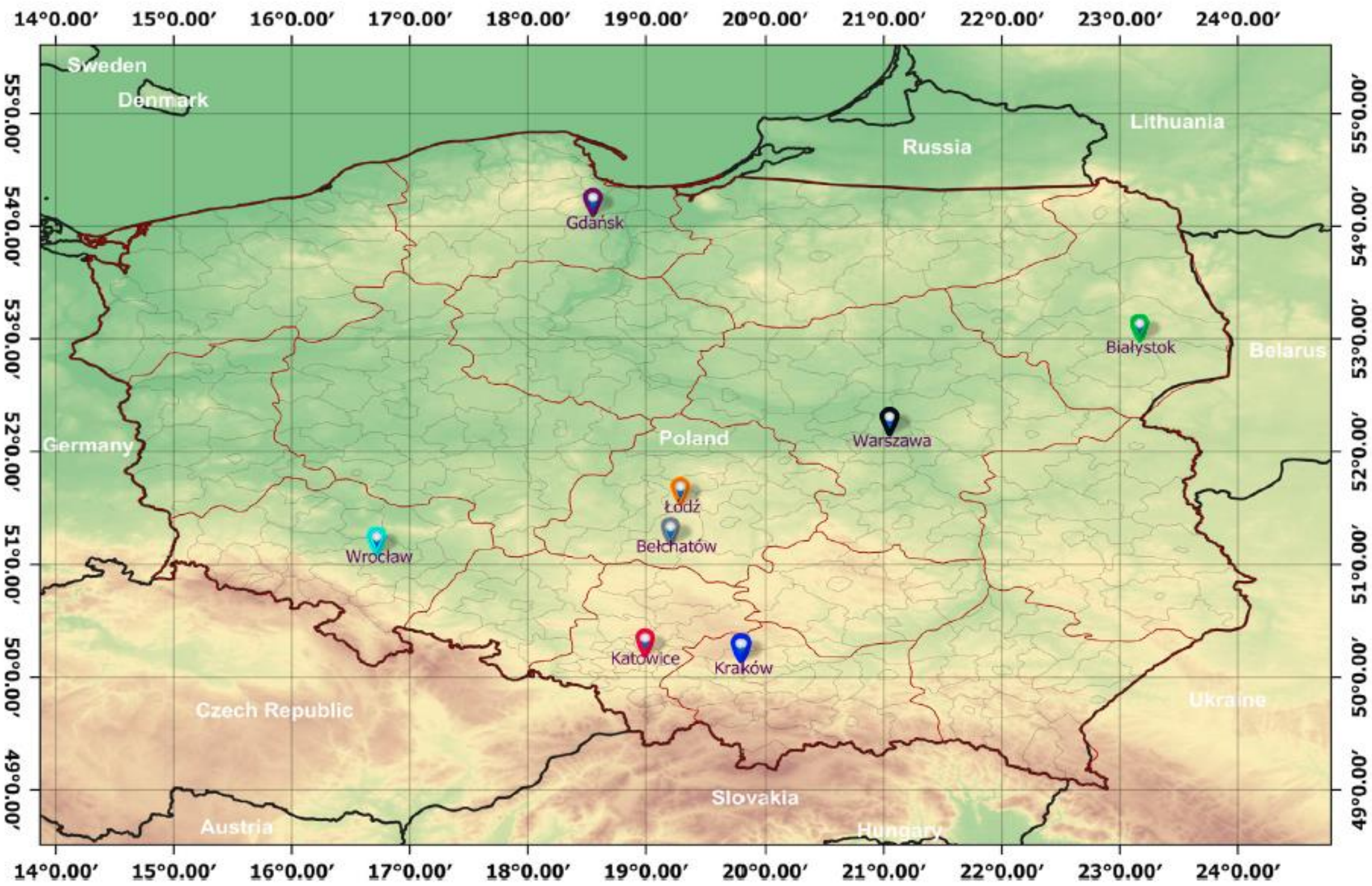


FIGURE 1

Map of Poland with locations of cities analysed in the study. Gdańsk (darkpurple), Białystok (green), Warszawa (black), Łódź (orange), Wroclaw (lightblue), Katowice (red), Kraków (blue), and Bełchatów power plant (gray).

Ugboma et al., 2023

Instruments and datasets

	OMI[1]	TROPOMI[2]
Launch date:	**15 July 2004 – now**	**13 October 2017 – now**
Spatial resolution:	**13 km x 24 km**	**3.5 km x 5.5 km**
Coverage:	**Global**	**Global**
Spectral:	**UV-1: 270 – 314 nm**	**UV and Vis: 270 – 495 nm**
	UV-2: 306 – 380 nm	**NIR: 675 – 775 nm**
	Vis: 350 – 500 nm	**SWIR: 2305 – 2385 nm**
Data products:	**Ozone, NO_2, SO_2, HCHO, BrO, OclO, Aerosol and cloud properties**	**Ozone, NO_2, SO_2, HCHO, CH_4, CO, Aerosol and cloud properties**

Data available > 5 years

Highly improved resolution

Extended spectrometers

More parameters

[1] https://aura.gsfc.nasa.gov/omi.html

[2] https://sentinels.copernicus.eu/web/sentinel/missions/sentinel-5p

Instruments and datasets

	ERA5 reanalysis[1]	EEA[2]
Meteorological parameters:	**100 m wind speed**	**Station-based NO_2**
	100 m wind direction	**Coverage: Bialystok, Gdansk, Lodz, Krakow, Warszawa, and Wroclaw.**
	Boundary layer height	
	2 m temperature	
Resolution:	**0.25º x 0.25º**	**Katowice?**
Duration:	**March – June 2019 -2020**	**2013 - 2020**

[1]https://www.ecmwf.int/en/forecasts/datasets/reanalysis-datasets/era5

[2]https://discomap.eea.europa.eu/map/fme/AirQualityExport.htm

Methodology

- NO_2 pollution fluctuate daily due to emission and weather changes, making it impractical to assess the lockdown's impact solely based on daily data.
- We averaged out the day-to-day meteorological variability in the TROPOMI NO_2 products by computing the 14-day simple moving average (SMA, as in Equation. 1)

$$\text{SMA} = \frac{a_{n-k+1} + a_{n-k+2} + \ldots + a_n}{k} \qquad (1)$$

where $a_1, a_2, \ldots, a_n$ represent daily data points.

The unweighted mean of the previous *k* data points is given by a SMA.

The higher the value of *k*, the smoother the curve; nevertheless, increasing *k* reduces accuracy.

Methodology

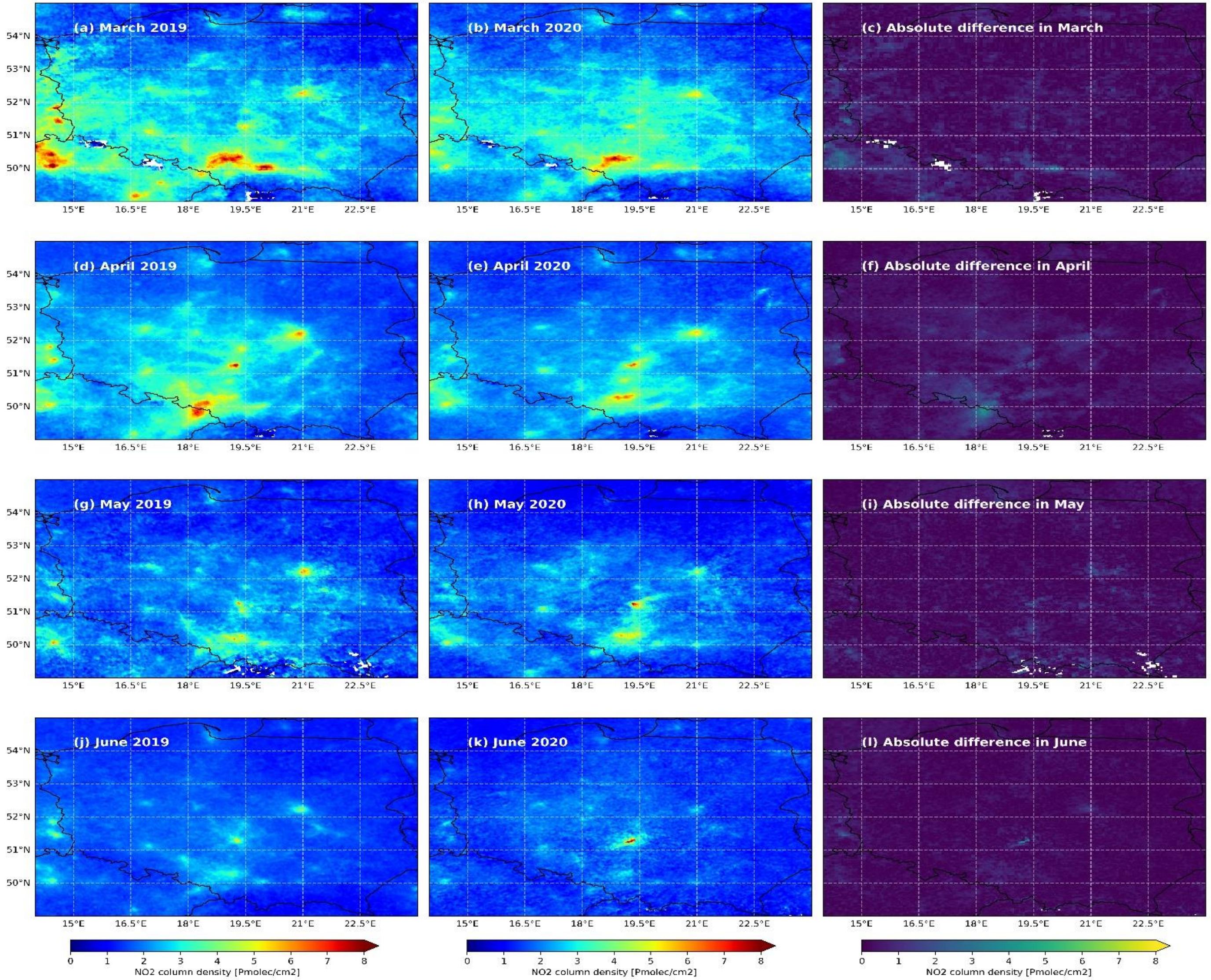
- The percentage relative change (RC) was used to assess how much the amount of NO_2 in the troposphere changed with respect to the reference period.
- In Equation 2, x_{20} and x_R represent the monthly mean NO_2 in the year 2020 and the long-term monthly average over the reference period from 2010 to 2019, respectively.
- The mean was computed after filtering OMI missing data points and outliers.
- This method allows for a more accurate comparison of NO_2 concentration variations.

$$RC = \frac{(x_{20} - x_R)}{x_R} \times 100 \qquad (2)$$

- HARP Atmospheric toolbox[1] by ESA was used to re-grid the TROPOMI dataset to 0.01° x 0.01°.
- Quality assurance value (qa_value) of >= 0.75 was applied to the TROPOMI data products.

[1] https://atmospherictoolbox.org/harp

Results: spatial map



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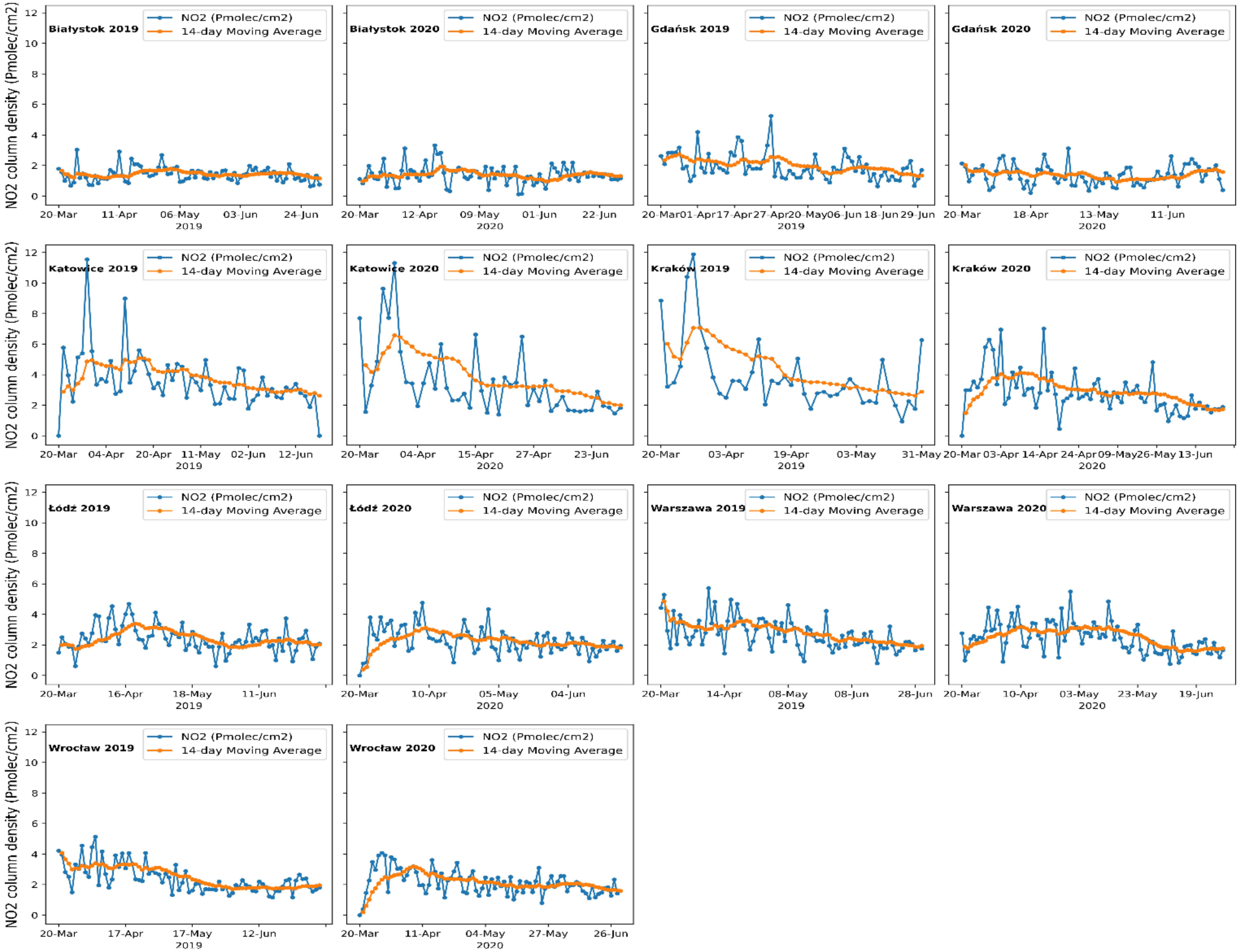
Results: 14-day moving average



TROPOMI NO_2 daily variations (blue) and a 14-day moving average (orange) in selected Polish cities (locations in Figure 1) between 20 March and 30 June of 2019 and 2020.

Extremely high variability in the cities

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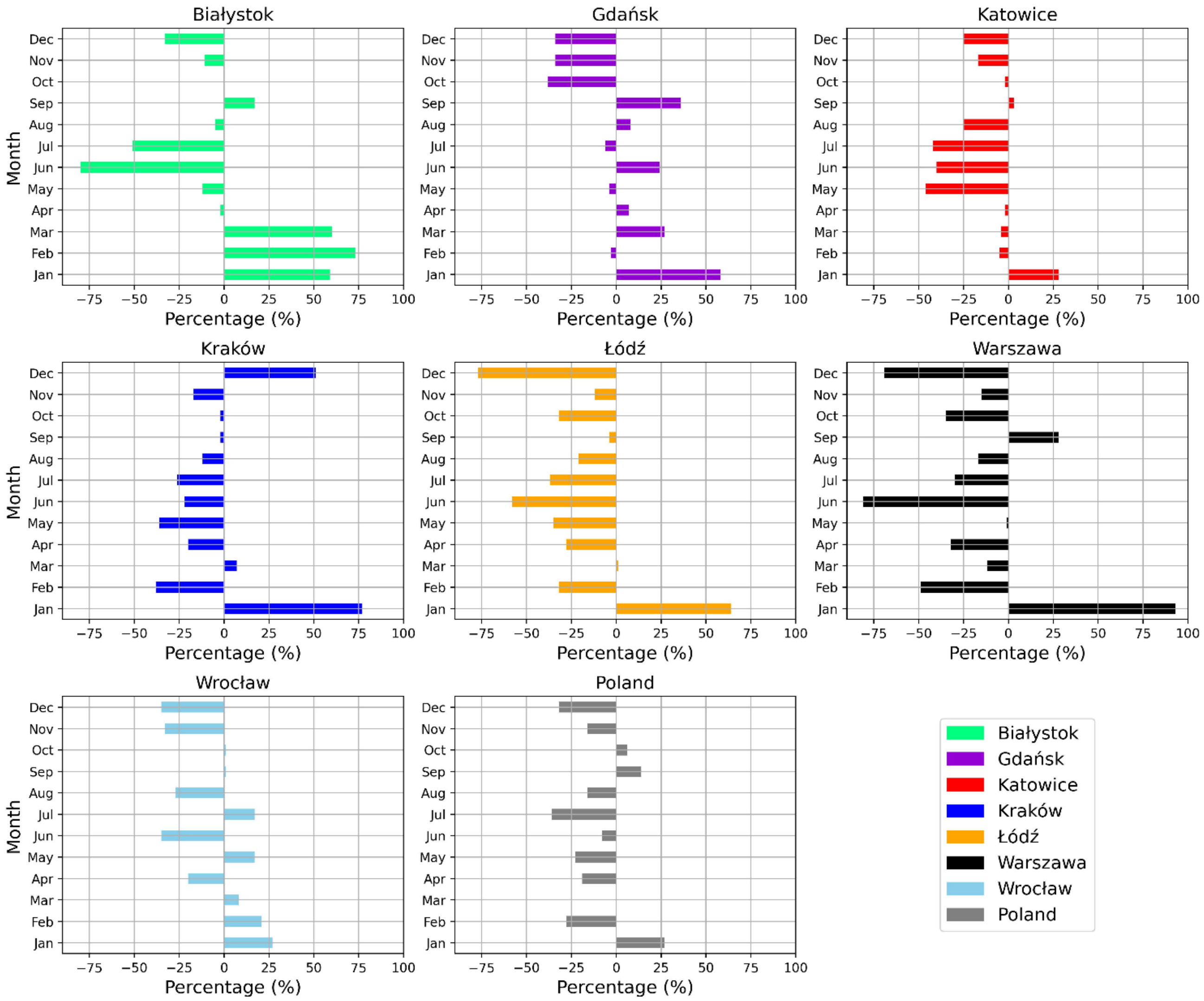
Results: Relative change

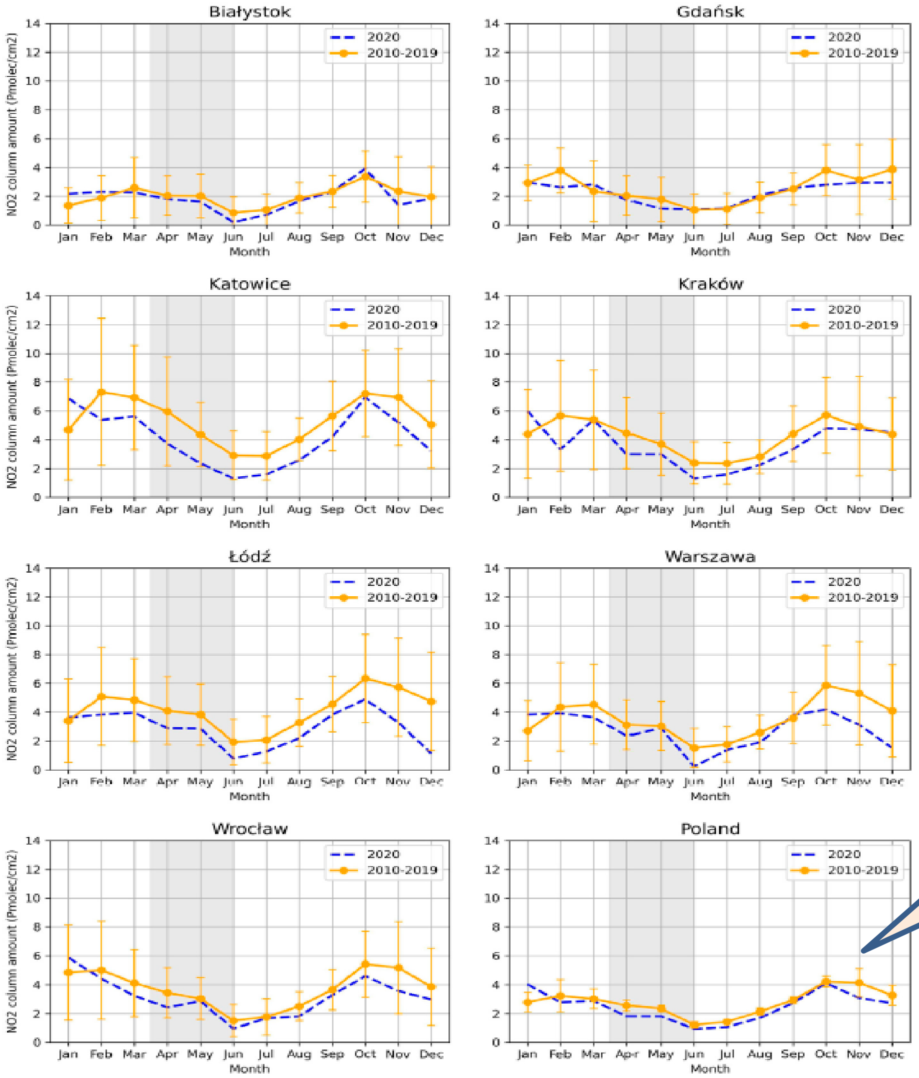


No strong decrease in Feb, March.
Not in the entire Poland nor in the cities

Relative change of the monthly mean OMI NO_2 concentration (2020 versus the 2010–2019 average) for selected Polish cities (in colors) and over the entire Poland (gray).

Ugboma et al., 2023

Results: Monthly mean + SD



Monthly mean NO_2 with standard deviation derived from OMI for Poland and the selected Polish cities in the COVID-19 year 2020 (blue dashed line) and in the reference period of 2010–2019 (orange line with error bar denoting the standard deviation).
The gray shade represents the COVID-19 lockdown period.

Lies within the variability.
Low variability in Poland

Ugboma et al., 2023

Conclusions

- During the lockdown (March to June 2020), we found strong sources of pollution in places like Katowice, Warszawa, and a power plant in Bełchatów.
- From 2010 to 2020, the long-term annual variability estimated from OMI tropospheric column NO_2 indicates a declining trend for major polluting cities (e.g., Katowice, Łódź), while none for cities (e.g., Białystok), where pollution levels were in general lower for the past decade.
- Although the relative change in 2020 to the average 2010–2019 for the entire Poland domain and for the major Polish cities shows a drop in OMI NO_2 levels during the lockdown, this change is not exceptional and lies within the year-to-year typical NO_2 variability.
- The TROPOMI NO_2 confirms that for the majority of the cities, the NO_2 drop during the COVID-19 lockdown was not clearly visible and did not follow the expected gradual change.
- Although meteorological conditions have a significant impact on the annual cycle of NO_2 in Poland, it is important to note that anthropogenic emissions remain the primary driver of NO_2 concentrations.

References

Relevant Publications

- Ugboma, E.A., Stachlewska, I.S., Schneider, P., & Stebel, K. (2023). Satellite observations showed a negligible reduction in NO_2 due to COVID-19 lockdown over Poland. *Front. Environ. Sci.*, 11, 1172753. https://www.frontiersin.org/articles/10.3389/fenvs.2023.1172753/full (and references therein)

Data availability

- Ugboma, E., and Stachlewska, I. (2022). NO_2 dataset over Poland and main Polish cities based on OMI observations (2010-2020), TROPOMI observations (2018-2021) and CAMS service (2018-2021). https://repod.icm.edu.pl/dataset.xhtml?persistentId=doi:10.18150/ZTD7FB

Acknowledgements

- The free use of Sentinel-5P/TROPOMI and Aura/OMI data is acknowledged.
- NASA ARSET Team for providing invaluable online training sessions that have greatly enhanced my knowledge and skills.
- HARMONIA-COST Action, for sponsoring my trip to ESA-ESRIN, Italy in 2023.
- Atmospheric Physics Department, IGFUW for sponsoring my trip to Norway in 2022.
- Special thanks go to my collaborators at NILU Norway for their contributions.
- The members of the Remote Sensing Lab have been incredibly helpful.
- Professor Stachlewska, my advisor, has provided solid encouragement and support.

Bardzo Dziękuję!