Air quality in Bucharest across the seasons

Validation of TROPOMI and WRF-Chem tropospheric NO_2 density against SWING+ and in situ measurements

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NO_x pollution in Bucharest, Romania

Nitrogen oxides (NO_x = NO + NO_2) significantly contribute to tropospheric pollution. NO_x are precursors to ozone (O_3) and particulate matter which are the main components of photochemical smog. These pollutants threaten human health, agriculture, and overall air quality.

Bucharest, the largest city in Romania, releases significant anthropogenic NO_x from power plants, traffic, industries, and other human activities, and is surrounded by rural areas. Seasonal changes affect NO_x photochemistry and both anthropogenic and soil emissions.

Objective: Use (1) in situ surface concentration data from the RNMCA network and (2) high-resolution airborne column measurements of SWING+ to evaluate TROPOMI nitrogen dioxide (NO_2) and the capability of the WRF-chem model to accurately capture the spatial and temporal variations of NO_2 abundances, in an understudied environment.

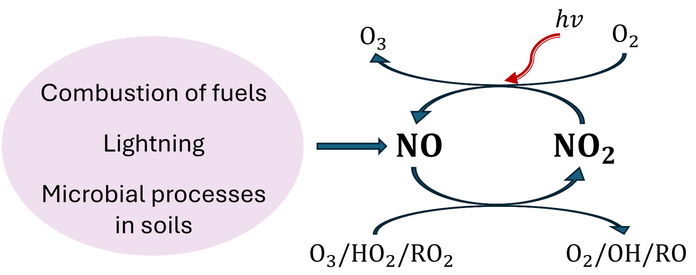

Fig. 1 : Production and photochemical cycle of NO_x species.

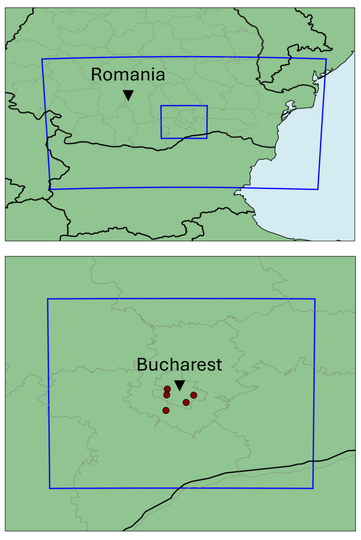

Fig. 2 : Outer (top) and inner (bottom) domains used in WRF-Chem with respective sizes 800x600 and 100x100 km². RNMCA stations appear in red.

Modelling with WRF-Chem

We employ WRF-Chem v4.5.1 to model the meteorology and air chemistry over two nested domains centered on Bucharest (*Fig. 2*). The vertical grid has 44 layers extending up to 20 km.

- Outer domain: horizontal resolution of 5 km.
- Inner domain: horizontal resolution of 1 km.

The model simulates the chemistry in the gas-phase and particulate composition using the MOZART mechanism and GOCART module. MEGAN biogenic emissions are computed online and anthropogenic emissions are taken from CAMS-REG v4.2 inventory (*Fig. 3*).

We perform two runs:
- *BASE*: using CAMS-REG v4.2.
- *EMX2*: with doubled anthropogenic NO_x emissions over Bucharest.

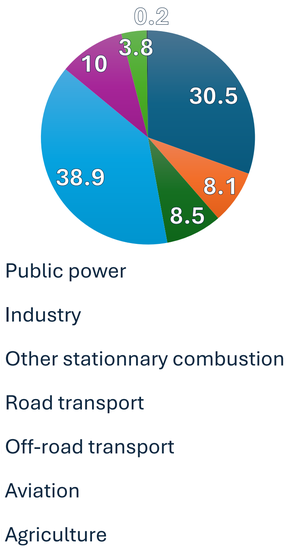

Fig. 3 : Sectoral contributions (%) to the total NO_x emissions over Bucharest in CAMS-REG v4.2.

Observational datasets

	RNMCA	SWING+	TROPOMI
Type	Ground-based in situ	Remote sensing from aircraft	Remote sensing from Sentinel-5 Precursor
Acquisition time	Every hour	17 two-hour flights across 2021 and 2022	Daily overpasses
Resolution	5 stations inside or near Bucharest	0.3 x 0.3 km² over Bucharest	5.5 x 3.5 km²
Above ground level	-	3 km	824 km
Product of intertest	Concentrations of NO_2	NO_2 tropospheric columns	RPRO NO_2 tropospheric columns

Evaluation of the WRF-Chem model

RNMCA vs WRF-Chem
NO_2 concentration (µg / m³)

SWING+ vs WRF-Chem EMX2
NO_2 column (molecules / cm²)

TROPOMI vs WRF-Chem EMX2
NO_2 column (molecules / cm²)

Fig. 4 : Evaluation of the WRF-Chem model against measurements from RNMCA (left), SWING+ (center), and TROPOMI (right). In each cell, we present the temporal/spatial average of NO_2 concentration/column for each data set, and the coefficient of determination R^2 between the data sets. For measurements from the RNMCA network, we provide averaged values from the five stations with metrics calculated using daytime data from the second day.

Validation of TROPOMI

Fig. 5 : SWING+ (left) and TROPOMI (right) NO_2 columns on 28/03/2022.

	SWING+	TROPOMI	R^2
11/11	3.2×10¹⁵	3.3×10¹⁵	0.92
05/01	3.2×10¹⁵	2.9×10¹⁵	0.59
23/08	3.3×10¹⁵	3.3×10¹⁵	0.90
30/06	3.7×10¹⁵	2.9×10¹⁵	0.81

Differences in instrument acquisition time and vertical sensitivity introduce representation errors that affect validation. This can be addressed by using WRF-Chem as an intercomparison platform (Poraicu et al., 2023).

Results and outlook

The plumes of NO_2 emanating from Bucharest are well-captured by WRF-Chem.

The model's performance varies by date, sometimes underestimating or overestimating observations.

➢ Explore the impact of modifications to the CAMS-REG inventory.

WRF-Chem vs TROPOMI indicates low modelled NO_2 levels outside the city.

➢ Review the sources of NO_x in rural areas (soil, lightning).

Improving the model's performance will allow us to validate TROPOMI against SWING+ with fewer representation errors.

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CAMS-REG Kuenen et al., *Earth System Science Data*, vol. 14, 491–515, (2022)
RNMCA https://www.calitateaer.ro (last access: 25-06-2024)
SWING+ Merlaud, Tack et al., *in preparation*
TROPOMI Van Geffen et al., *Atmospheric measurement Techniques*, vol. 15, 2037-2060 (2022)
Poraicu et al., *Geoscientific Model Development*, vol. 16, 479–508 (2023)

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