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EXTENDED ABSTRACT

Assessment of tropospheric ozone production from biogenic VOCs and traffic pollutant emissions in Lecce using ADMS-Urban

Riccardo Buccolieri, University of Salento, Lecce, Italy; RESEAUX S.r.l., Lecce, Italy

riccardo.buccolieri@unisalento.it

Gianluca Pappaccogli, University of Salento, Lecce, Italy; Chiara Metrangolo, University of Salento, Lecce, Italy; Antonio Esposito, University of Salento, Lecce, Italy; Rita Cesari, National Research Council of Italy (CNR-ISAC), Lecce, Italy

1. Abstract

This study aims to quantify the combined impact of biogenic VOCs (bVOCs) and traffic emissions on O_3 formation in a specific district of Lecce (Italy) during a representative summer period. The research combines real-time field measurements of traffic activity, meteorological variables and pollutant concentrations with numerical simulations. The bVOC fluxes were estimated considering the vegetation present in the study area, then the ADMS-Urban dispersion model was employed.

1. Introduction

Tropospheric ozone (O_3) forms through complex photochemical reactions involving mainly nitrogen oxides (NO_X) and volatile organic compounds (VOCs) and depends on the local photochemical regime. The Mediterranean often experiences high ozone levels. In urban areas, both traffic emissions and biogenic VOCs (bVOCs) from vegetation contribute. In Mediterranean cities, high summer solar radiation and temperatures enhance the role of bVOCs in ozone formation, because we are often in VOC-limited regime due to the high NOx emissions (Calfapietra et al., 2013).

This study focuses on the most relevant bVOCs, namely isoprene (C_5H_8) and monoterpenes ($C_{10}H_X$), to provide an assessment of O_3 formation in a specific district of Lecce (Italy). The objective is to quantify the combined impact of traffic-related NO_X and VOCs and bVOCs from tree species. The research integrates an experimental campaign with dispersion and photochemical modelling using ADMS-Urban (www.cerc.co.uk).

2. Methodology

2.1 Study area

The study has been conducted in a specific urban district of Lecce, Southern Italy, centered around the Deledda high school (Figure 1). The chosen area is characterized by a mix of residential and educational buildings and includes existing vegetation.

Figure 1. Study area in Lecce (Italy), indicating the location (green point) of the meteorological, air quality and traffic-counting stations.

2.2 Field measurements

An integrated monitoring station was deployed at the Deledda high school, comprising three main components for comprehensive environmental data collection (Figure 1): air quality and meteorological stations (AIRQINO SMART TRAFFIC) mounted at approximately 2 m above ground level and providing real-time measurements of key air quality parameters and meteorological variables (https://map.airqino.it); and a traffic counting camera (FLOUD) at around 4 m above ground, monitoring vehicular activity, classifying vehicles into different categories (bikes, motorbikes, economy cars, sedans, trucks, buses) and estimating their speeds (https://unisalento.floud.eu). Measurements from the station have been continuously available since 24 March 2025.

2.3 Numerical modeling

The study employs the ADMS-Urban dispersion model to simulate pollutant concentrations and O_3 photochemistry within the study area. The model incorporates a “Generic Reaction Set” (GRS) with seven reactions that effectively capture the key photochemical pathways by which NO_x and hydrocarbons are converted into O_3. The ADMS default VOC parameters were defined as a weighted value considering traffic ($E_{traffic}$) and trees (E_{trees}) emissions to represent mixed anthropogenic and biogenic VOCs in the study area. Since biogenic VOCs are more reactive, the AROC reactivity coefficient in the GRS scheme was increased from the default value of 0.05 to 1. This adjustment’s impact on ozone formation in the same city was assessed in Cesari et al. (2021). Numerical simulations were performed for a representative summer period, specifically from 1 to 7 July 2025. Hourly background concentrations for O_3, NO_X and VOCs were obtained from the Copernicus Atmosphere Monitoring Service (CAMS) (https://ads.atmosphere.copernicus.eu/datasets/cams-europe-air-quality-forecasts?tab=overview). The input meteorological data were obtained by the Ateneo meteorological station (40°21'22.22"N, 18°10'4.59"E) located in the city centre of Lecce at 11m a.g.l., operated by the OMD Foundation (Osservatorio Meteo Milano Duomo; https://www.fondazioneomd.it) and located 11 m above ground level.

2.3.1 Estimation of biogenic emissions

The biogenic emission flux F (μg m^{-2} h^{-1}) have been evaluated (Guenther et al. 1993; Simpson et al. 1999) by $F = \varepsilon D \gamma$, where ε is the emission rate expected for a particular plant species at a reference temperature of 300 C and PAR of 1000 mmol photons (400-700 nm) m^{-2} s^{-1}; D is the foliar biomass density (g dry weight (DW) m^{-2}). γ is a dimensionless environmental correction factor that accounts for emission response to environmental conditions (Guenther et al., 2012). For isoprene emission the correction factor γ_{iso} has been calculated as the product of two coefficient C_L and C_T, which account respectively for the effect of PAR levels and leaf temperature. Regarding monoterpene emissions, for some species the environmental correction factor γ_{mono} depends primarily on temperature alone, while for others it follows the same dependency as isoprene, and is therefore calculated as the product of C_L and C_T. The meteorological values used to calculate the correction factor were derived from data ERA5 reanalysis dataset available through the Copernicus Climate Data Store (C3S) (https://cds.climate.copernicus.euhttps://cds.climate.copernicus.eu). The emission potential ε and the foliar biomass density D were defined using literature-based values (Simpson et al., 1999, Klinger at al., 2002). The species prevalent in the study area are: Cypress (*Cupressus arizonica* Greene, *Hesperotropsis leylandii* (A.B.Jacks. & Dallim.) Garland & Gerry Moore), Aleppo Pine (*Pinus halepensis* Mill. 1768), Holm Oak (*Quercus ilex* L., 1753), Ficus ginseng (*Ficus microcarpa* L.f., 1782), Pino domestic (*Pinus pinea* L., 1753). These tree species were modelled as area sources within ADMS-Urban, reflecting their spatial distribution.

2.3.2 Estimation of traffic emissions

Traffic emissions of NO_X, NO_2 and VOCs were computed within ADMS-Urban using the model’s internal dataset “UK EFT v9.0 (2VC)”, specifying the emission year as 2025 and designating “England (urban)” as the road type. These factors are applied to the detailed traffic data (vehicle counts, speeds and fleet composition) obtained from the traffic counting camera (Figure 2). The street section adjacent to the Deledda school (where the monitoring station is located) was modeled as a road source with its specific morphological characteristics (height to width ratio equal to 1.6); both the effect of street canyons and traffic-induced turbulence were included.

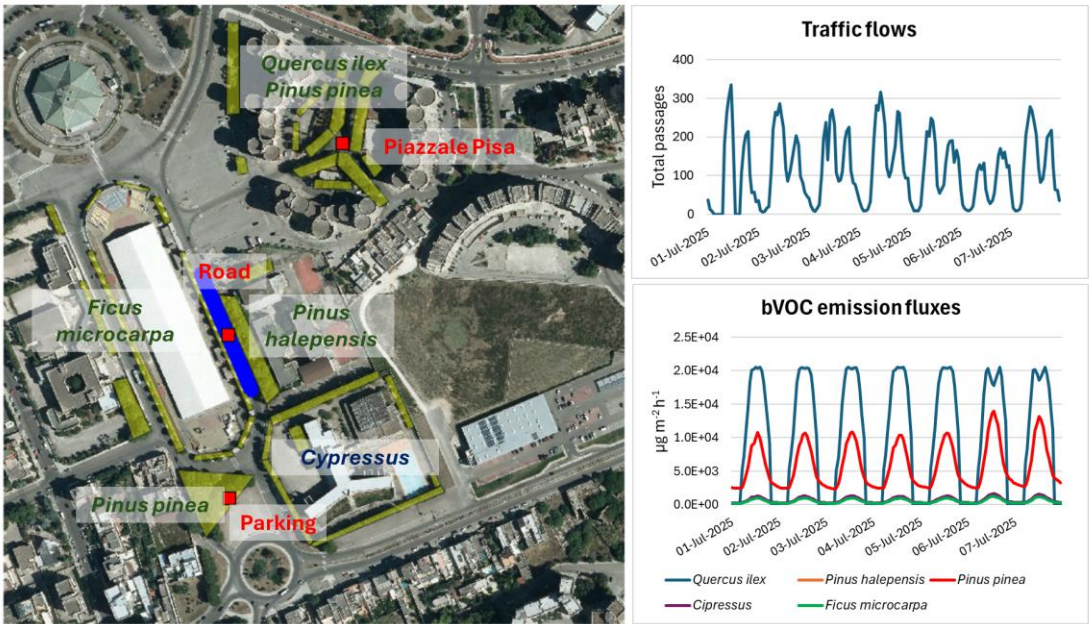

Figure 2. Representation of the study area in ADMS-Urban, showing the road as a line source (blue line), trees as area sources (yellow polygons) and receptors (red points) (left); traffic flows (top, right) and bVOC emissions from trees (bottom, right).

3. Results

Figure 3 presents the percentage differences in O_3 concentrations at three specific receptor locations (see Figure 2) ($C_{trees} – C_{back+traffic}$) / $C_{back+traffic}$, where C_{trees} is the concentration obtained when also trees emissions were active in the model, while $C_{back+traffic}$ include only background and traffic contributions. The results show daily peaks in O_3 concentration differences, particularly during the morning hours of 6 and 7 July. These peaks generally align with periods of high bVOC emissions (as shown in Figure 2) and strong solar radiation, which drive the photochemical reactions leading to O_3 formation. Specifically, Piazzale Pisa, where *Quercus Ilex* and *Pinus pinea* are present, frequently shows the highest percentage increases in O_3, reaching about 5.5%. This can be attributed to the high bVOC emission potential of these species, which, in the presence of NO_X from traffic emissions, facilitates enhanced O_3 production. The parking area, predominantly featuring *Pinus pinea*, also exhibits significant increases, reaching nearly 4%. The Road receptor generally shows smaller, though still positive, percentage differences, which might be influenced by a more immediate titration effect from fresh NO emissions from traffic and potentially less direct exposure to dense bVOC sources compared to the other two locations which are closer to larger vegetated areas. The largest differences in ozone formation are observed in the early morning, possibly due to a VOC-limited regime under high NOx conditions, where even moderate bVOC emissions can significantly enhance photochemical ozone production.

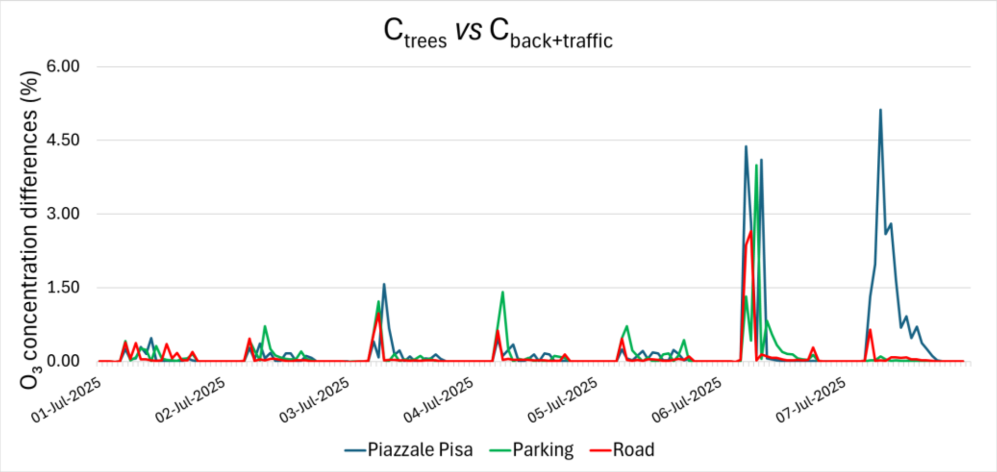

Figure 3. Percentage differences in O_3 concentrations at three receptors, comparing simulations with active tree emissions vs. background and traffic only.

Conclusions

This study shows that bVOC emissions from trees, especially high emitters like *Quercus ilex* and *Pinus pinea*, can enhance O_3 formation. Therefore, vegetation type should be considered in urban air quality strategies and green space planning.

Acknowledgements

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