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SEASONAL AND TEMPORAL BEHAVIOR OF AIR POLLUTION OVER SOFIA CITY FOR THE PERIOD FROM 2007 TO 2025 BASED ON SATELLITE AND GROUND DATA

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Key words: *air pollution, remote sensing, satellite data*

Abstract

In the paper, we study seasonal and temporal air pollution trends over the city of Sofia for the period from the beginning of 2007 to the end of 2025. We use data from all Automatic Ground Measurement Stations and satellite data from the MetOp A and B satellites. We investigated all pollutants, such as SO_2, NOx, CO, O_3, and others. The only pollutants that show significant values, close to or above the limits here, are dust particles and NO_x, so we present results only for these pollutants. We also use ground temperature data and present the results of its seasonal and temporal trends.

Introduction

Cities are often hotspots for poor air quality. As rapid urbanisation increases the number of people breathing dangerously polluted air, city-level data can help inform targeted efforts to curb urban air pollution and improve public health. Outdoor air pollution is a major environmental health problem affecting everyone in low-, middle-, and high-income countries.

Air pollution in both cities and rural areas was estimated to cause 4.2 million premature deaths worldwide per year in 2019; this mortality is due to exposure to fine particulate matter, which causes cardiovascular and respiratory disease, and cancers [1].

Air pollutants can be of natural (biogenic), anthropogenic or mixed origin, depending on their sources or the sources of their precursors 1. They are categorised as primary or secondary. Primary pollutants are emitted directly into the atmosphere, while secondary pollutants are formed by interaction with other substances (precursors) through chemical reactions and microphysical processes. Primary air pollutants are fine particulate matter (PM), black carbon (BC), sulphur oxides (SO_x), nitrogen oxides (NO_x) (including both nitric oxide (NO) and nitrogen dioxide (NO_2)), ammonia (NH_3), carbon monoxide (CO), methane (CH_4), nonmethane volatile organic compounds (NMVOCs), including benzene (C_6H_6), some metals and polycyclic aromatic hydrocarbons (PAHs), including benzo[a]pyrene (BAP). Secondary air pollutants are PM (formed in the atmosphere from SO_2, NOx, NH_3 and VOCs), ozone (O_3), NO_2 and several volatile organic compounds (VOCs).

Particulate matter, nitrogen dioxide and ground-level ozone are now generally recognised as the three pollutants that have the greatest impact on human health. Long-term exposure to high levels of these pollutants ranges in severity from respiratory damage to premature death. Around 90% of European city dwellers are exposed to concentrations above levels considered harmful to health [2].

Sofia, the capital city of Bulgaria, is unfortunately exposed to high levels of particulate matter (PM), despite extensive efforts by the government and the municipality in recent decades, and some authors have tried modelling air quality there [3, 4].

Air quality monitoring is mainly carried out using three methods – satellite data, ground-based measurements and unmanned aerial vehicles. Satellite data show the presence of individual pollutants in the column of atmospheric air from the ground surface to the measuring device, but with relatively low spatial and temporal resolution. Ground-based measurements (mainly from AIS) provide accurate quantitative measurements with good temporal resolution, but only for a small area around their location. Unmanned aerial vehicles provide the intermediate between the two, namely – the possibility of dynamic measurements at different heights and locations. Then, present satellites measure only Aerosol indexes, but not PM_x concentration and NO_2 only [5]. Automatic Ground Measure Stations (AGMS) in Sofia provide data for NO, NO_2, NO_x, PM2.5 and PM10 [5].

In this paper, we use both satellite and ground measurement data to inspect temporal and seasonal trends of main air pollutants in Sofia.

Data and Method

In this work, we use monthly values of the Absorption Aerosol Index and NO2 from MetOp A and B satellites [5] for the period November 2007 to the end of 2025. Data from MetOp A is available till the end of 2020, while data from MetOp B starts at the beginning of 2013. We use data from all AGMS in Sofia, including Mobile station and two new stations – those in Busmanci and Trebich [6] for the period from the beginning of 2007 till the end of 2025. In Fig. 1, we show their locations. In Fig. 2, we show a working time diagram. We use data from the mobile station only for these periods, when it stays in the parking zone at Paris 5 Str.

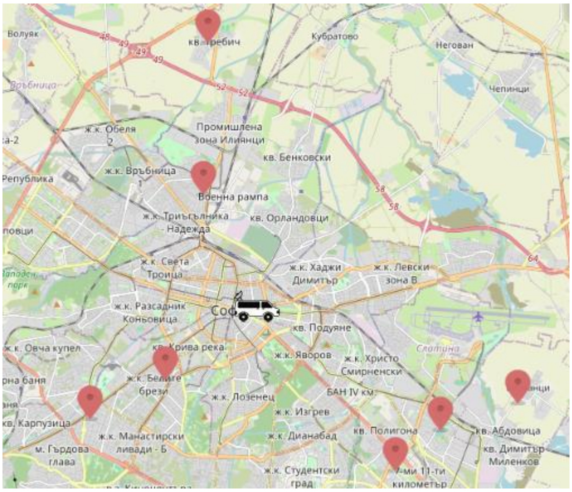

Fig. 1. AGMS positions in Sofia

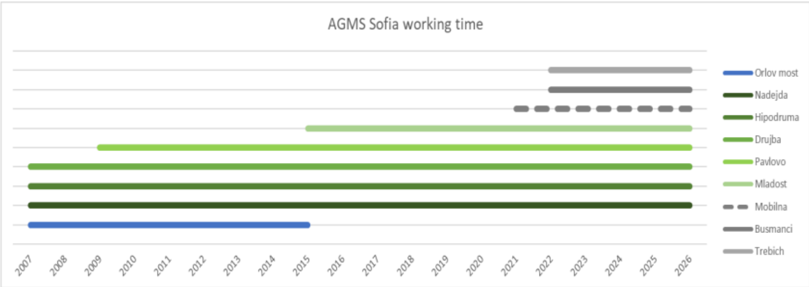

Fig. 2. AGMS in Sofia – working time diagram

Data from AGMS is provided in daily base and here we average it over every month.

We build seasonal and temporal trends for AAI and NO_2 from satellite data and seasonal and temporal trends for all pollutants from AGMS – PM2.5, PM10, NO, NO_2, NO_x, SO_2, CO and O_3. Temporal trends are obtained by averaging monthly data for each year and seasonal averaging monthly values for each month over years [7].

We build seasonal and temporal trends for averaged daily temperature only to show its significant increase over the last few years.

In Sofia, only PMx and NOx data show values close to or above the obtained maximal limits, so we study them in more detail.

Monthly values for AAI are with spatial resolution 1 x 1 degree, while NO_2 are with resolution 15 x 15 minutes (or 1/4 degree). In both cases, Sofia is placed in only one pixel. In Fig. 3, we illustrate pixel sizes for the AAI and NO2 columns, respectively.

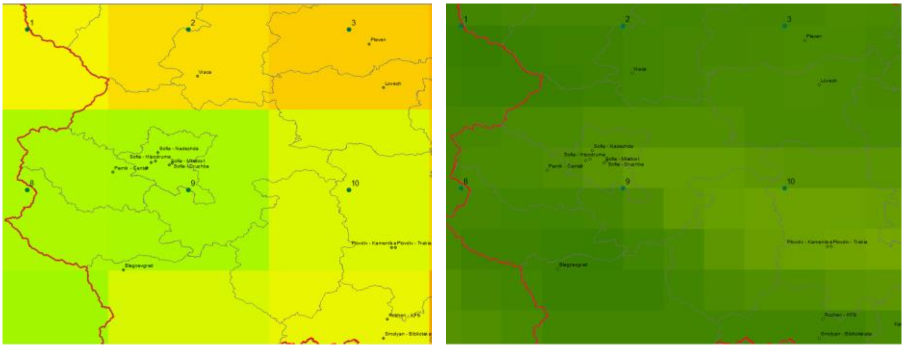

Fig. 3. Spatial resolution of MetOp A and B for AAI and NO_2

Results

In Fig. 4 and Fig. 5, we show temporal and seasonal AAI behaviour, respectively.

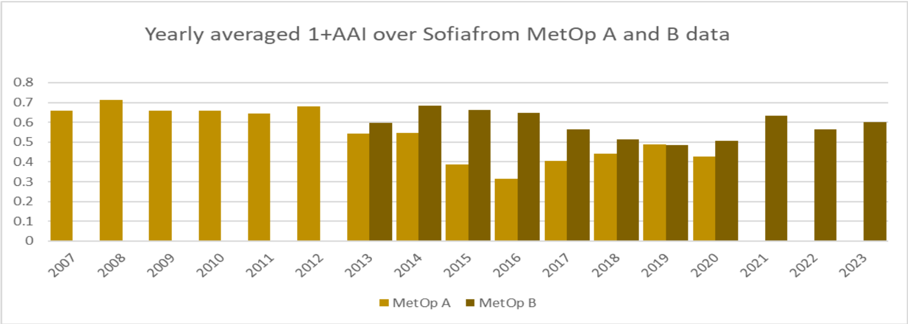

Fig. 4. Temporal AAI trend in Sofia

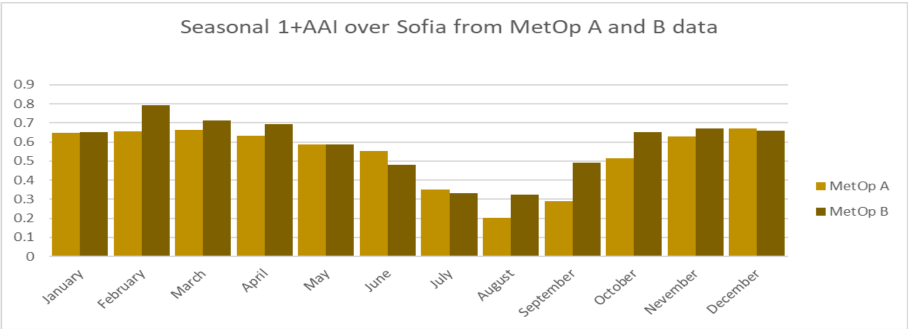

Fig. 5. Seasonal AAI trend in Sofia

In Fig. 6 and Fig. 7, we show the same trends for MP10, obtained from AGMS.

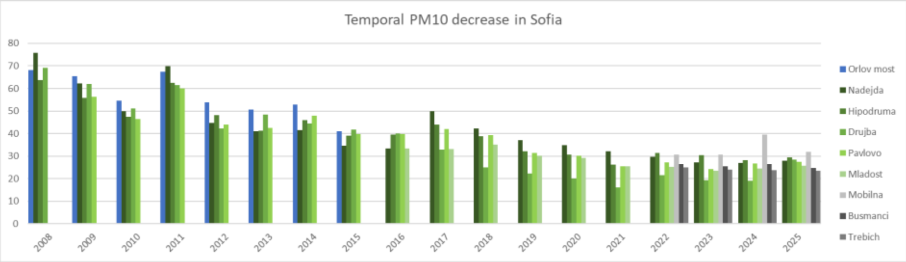

Fig. 6. Temporal PM10 trend in Sofia

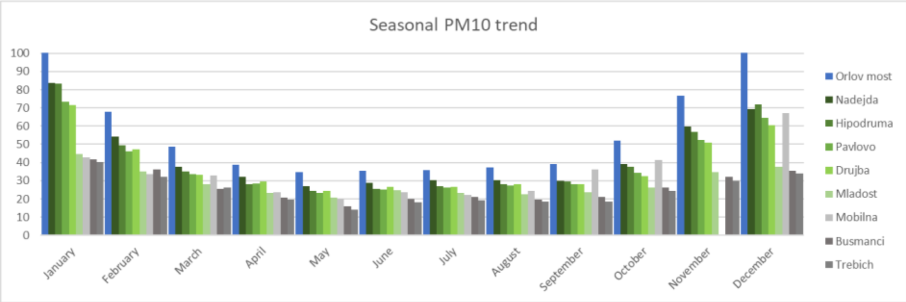

Fig. 7. Seasonal PM10 trend in Sofia

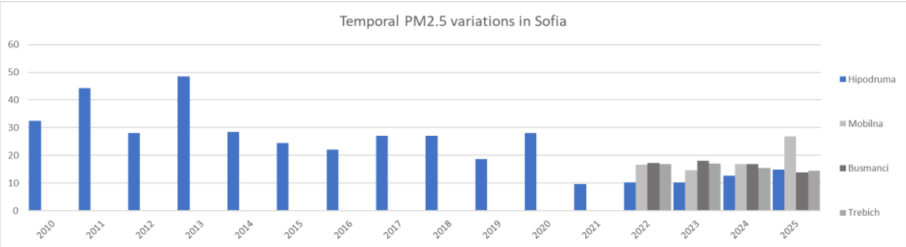

Fig. 8. Temporal PM2.5 trend in Sofia

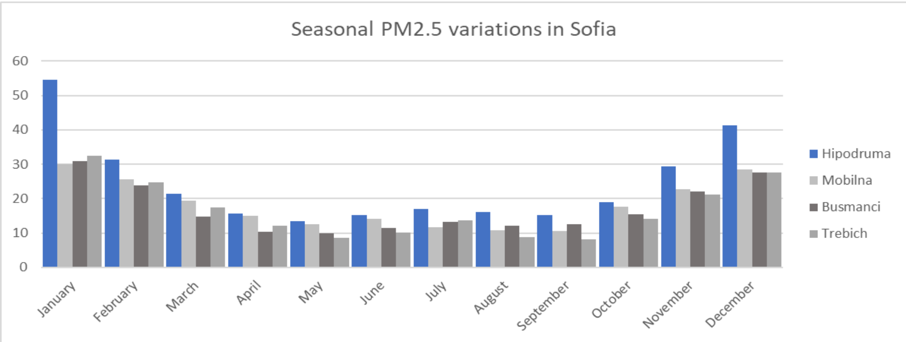

Fig. 9. Seasonal PM2.5 trend in Sofia

In Fig. 8 and Fig. 9, we show temporal and seasonal trends for PM2.5.

In all figures from AGMS, we use the same colours for all measurement stations for easier comparison.

In Fig. 10 and Fig. 11, we show temporal and seasonal NO2 behaviour obtained from MetOp A and B data, respectively.

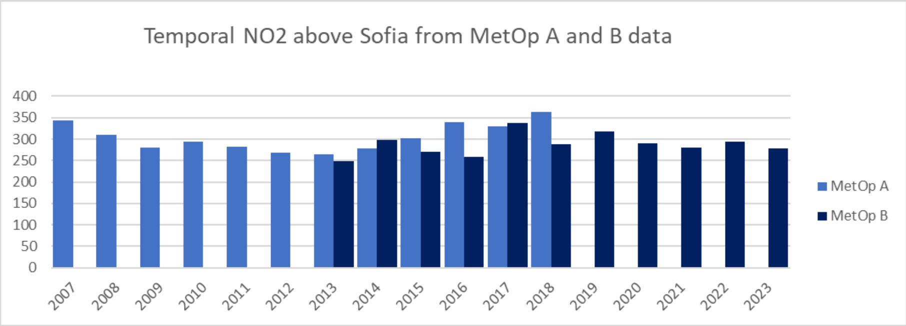

Fig. 10. Temporal NO_2 trend above Sofia

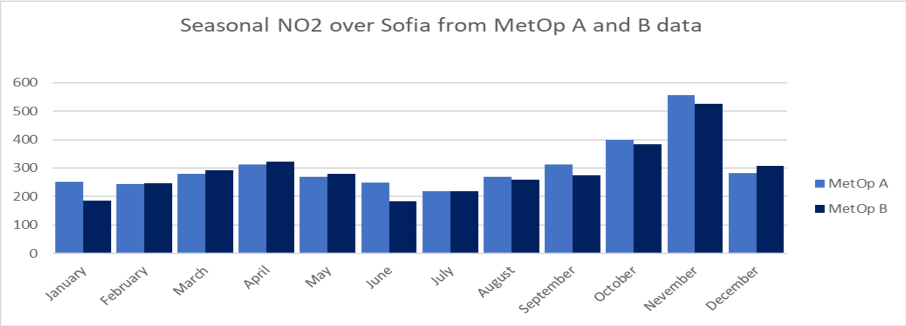

Fig. 11. Seasonal NO_2 trend above Sofia

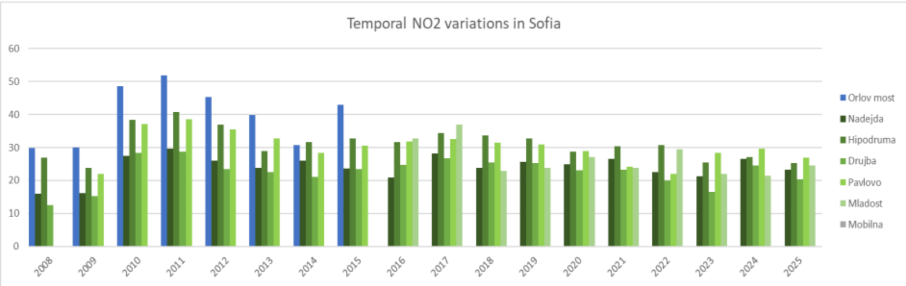

Fig. 12. Temporal NO_2 trend in Sofia

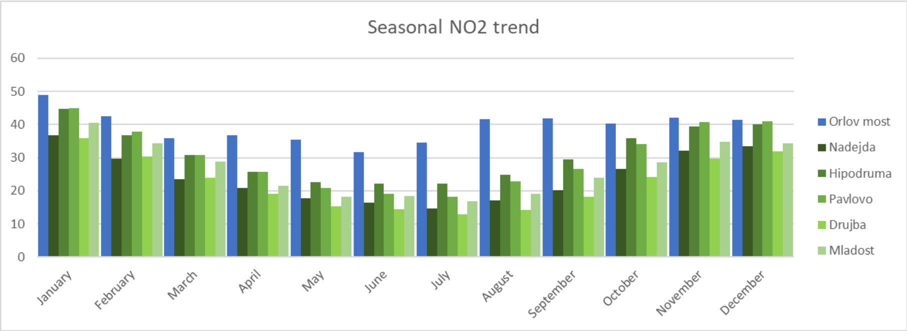

Fig. 13. Seasonal NO_2 trend in Sofia

In Fig. 12 and Fig. 13, we show temporal and seasonal NO2 behaviour obtained from AGMS in Sofia.

Seasonal and temporal trends of NO and NO_x are similar to those of NO_2.

In Fig. 14, we show temporal and seasonal trends for total NO_x, SO_2, CO, and O3 at the Hipodruma station.

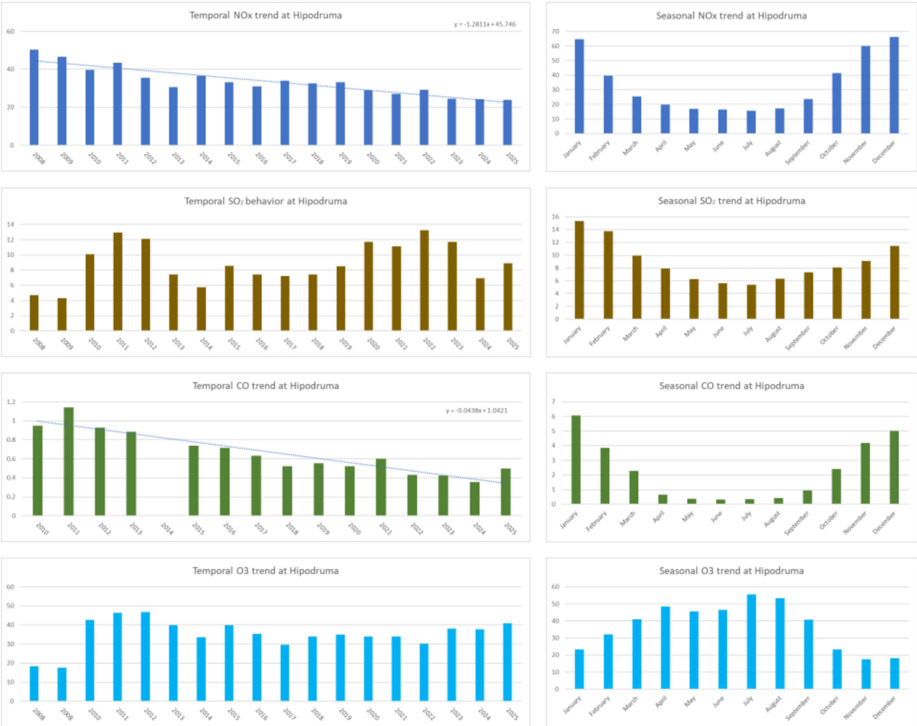

Fig. 14. Temporal and seasonal SO_2 CO and O_3 trend in Sofia

In Fig. 15 and Fig. 16, we show temporal and seasonal temperature increases obtained from AGMS in Sofia.

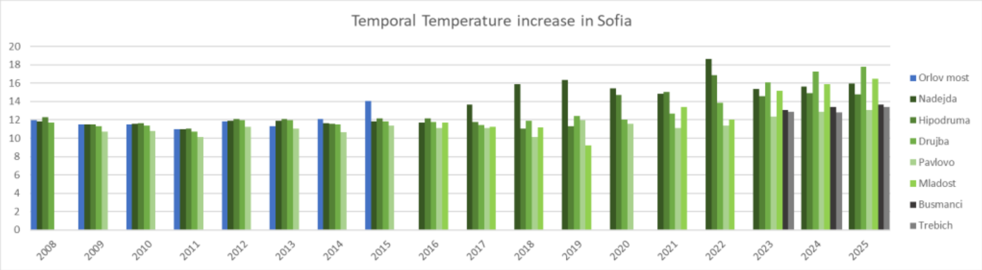

Fig. 15. Temporal temperature trend in Sofia

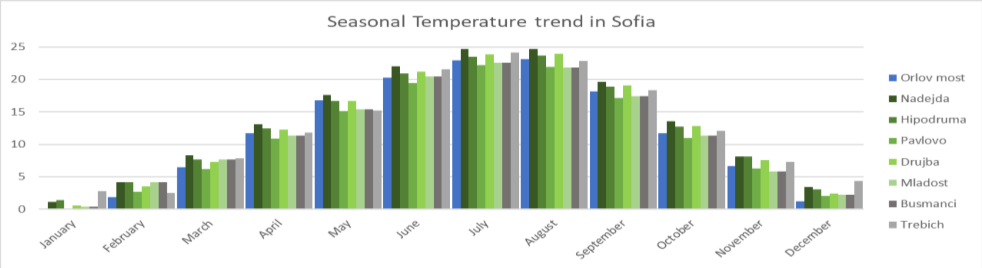

Fig. 16. Seasonal temperature trend in Sofia

Discussion and conclusions

As we see from Fig. 4 and Fig. 6, seasonal trends of AAI and PM show similar behaviour. The same is seen for NO2, NOx, SO2, and CO from AGMS. All NO, NO_2 and NOx show nearly equal trends. All these pollutants have their maximum in January, February and December. NO_2, measured from satellite data, shows a different seasonal trend – it has a maximum in November.

Near-ground O3 shows a different seasonal trend, too. Its monthly values are higher in summer and show a maximum in July and August.

While AAI and NO_2 from satellite data show no temporal trend, PM10 and NO_2 at the ground show a significant decrease over the years. A significant decrease trend shows CO too. SO_2 and O_3 show no temporal trend.

Yearly averaged air temperature, measured from AGMS, shows an increase of about 40–50% during the last five years.

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СЕЗОННО И ВРЕМЕННО ПОВЕДЕНИЕ НА ЗАМЪРСЯВАНЕТО НА ВЪЗДУХА НАД ГРАД СОФИЯ ЗА ПЕРИОДА ОТ 2007 ДО 2025 Г. ВЪЗ ОСНОВА НА СПЪТНИКОВИ И НАЗЕМНИ ДАННИ

М. Димитрова

Резюме

В настоящата статията изследваме сезонните и времеви тенденции на замърсяване на въздуха над град София за периода от началото на 2007 г. до края на 2025 г. Използваме данни от всички автоматични наземни измервателни станции (АИС) и сателитни данни от спътниците MetOp A и B. Всички замърсители като SO_2, NOx, CO, O_3 и други са разгледани. Единствените такива, които показват значителни стойности, близки или над пределно допустимите норми тук са праховите частици и NOx, така че представяме резултати само за тези замърсители. Използваме и наземни данни за температурата и представяме резултатите за тяхното времево и сезонно поведение.