A case study of high PM concentration despite the low anthropogenic pollution in March 2020 during the first COVID-19 lockdown in Sofia

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Abstract

The aim of this study is to investigate the atmospheric air quality in Sofia during a 2-week period in the beginning of the first COVID-19 lockdown in March 2020. Observations of the aerosol distribution measured with two laser particle counters for PM2.5 and PM10 on clear sunny days (7 a.m. to 2 p.m.) at a site inside the built area near the bus stop Pliska on the Tsarigradsko shose during 16-31 March 2020 are presented. Mass and particle number concentrations of PM with high temporal resolution are compared with the data reported by Executive Environmental Agency monitoring network. In the beginning of the period the concentrations of PM10 vary between 20 and 80 μg/m3 with a peak around 9 - 10 a.m and PM2.5 concentrations reach 30 μg/m3. On 28 March at 9 a.m. the PM10 and PM2.5 concentration raise up to 250 μg/m3 and 175 (μg/m3), correspondingly. This abrupt change in the aerosol content in the atmosphere is explained not with anthropogenic load, but with long range dust transport from the Karakum desert region (located between the eastern coast of the Caspian Sea and the steppes near the central Asian mountain ranges), which is a very rare event of intrusion compared to the typical in spring Sahara dust transport. The HYSPLIT back trajectory model is used as additional source of information in the selected days, showing transport in the layer 1000 m – 3000 m from North-West until 26 March and from East on 27-29 March. The GDAS boundary-layer depth at 12 UTC is between 1000 m and 1600 m which suggest intrusion from above during the period. These model data are compared to local meteorological and aerological observations. This study shows the importance of detailed in time laser particle counter observations of PM10, PM2.5 and finer particles for better explanation of causes for the low air quality in urban atmosphere.

Introduction

The aerosol characteristics of interest concerned in the work are shown respectively parameters: the aerosol number and mass concentration in the near-ground urban atmosphere, the height of the atmospheric boundary layer (ABL), the meteorological parameters influencing the aerosol properties and atmospheric dynamics. The combination of atmospheric transport models and particle counter measurements provides comprehensive information on both the aerosols concentration characteristics in the urban atmosphere as well as about the vertical structure of aerosol layers and meteorological parameters determining the transport of air mass of Sofia, Bulgaria. In this study, we record for the first time a dust intrusion from the Asia region. Our results are confirmed by the observations of the atmosphere of Italian colleagues from three cities (Tositti L. et all., Development and evolution of an anomalous Asian dust event across Europe in March 2020, Atmos. Chem. Phys., 22, 4047–4073, 2022). In addition to LPC, their experiment uses ceilometer and sun photometer data. In conclusion, we would note that the increased concentrations of aerosol particles are due to the influx of dust from Asia and the lower ABL due to its reflection of solar energy back into the atmosphere. In our other studies, we have already shown that in the Sofia Bulgaria region, the influence of dust from the Sahara is more often observed. In this case, two routes are observed: Sahara-Greece-Bulgaria and Sahara-Spain-Europe-Bulgaria.

Instruments

Laser particle counter (*LPC - BQ20, TROTEC, Germany*) comprises two contact measurement channels. The first, PM2.5 channel selects the aerosol particles of sizes from 0 to 2.5 μm, the second - PM10 channel, selects the particles of sizes from 2.5 to 10 μm. In both channels the particle size and the particle number and mass concentration are measured with temporal resolution from 10 to 15 min and sampling rate of 0.9 l/min. Measurements were performed near bus stop Pliska, 100 m South of Blvd. "Tsarigradsko shose", one of the largest boulevards in Sofia with heavy traffic. WRF-GDAS of NOAA Air Resources Laboratory (https://www.ready.noaa.gov/) was used for estimation of the atmospheric boundary layer height (ABLH).

HYSPLIT (http://www.arl.noaa.gov/ready/hysplit4.htm) was used for recognition of the origin and transport of the air mass reaching Sofia at different heights during different case study experiments.

RESULTS AND DISCUSSION

The experiments were carried out on sunny days and days with dust intrusions from the Karakum desert region of the central Asia. The results obtained over three days (18.03.2020, 21.03.2020, and 28.03.2020) are analyzed here based on Laser particle counter measurements of number and mass PM10 and PM2.5 concentrations; model forecast for Boundary Layer Depth results for Sofia with WRF-GDAS model; air mass back-trajectories calculated by the HYSPLIT model ending over Sofia on 18 March 2020 and 28 March 2020.

Laser Particle Counter Data

FIGURE 1. Daily variations in PM2.5 and PM10 on 18 March 2020 and 28 March 2020 measured as particles per liter (N/L)

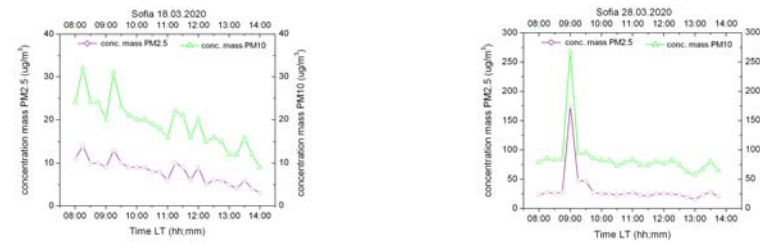

FIGURE 2. Daily variations in PM2.5 and PM10 on 18 March 2020 and 28 March 2020 measured as particles per concentration mass (μg/m3)

WRF-GDAS model forecast for Boundary Layer Depth (Zi) over Sofia and HYSPLIT Back Trajectory Model Data

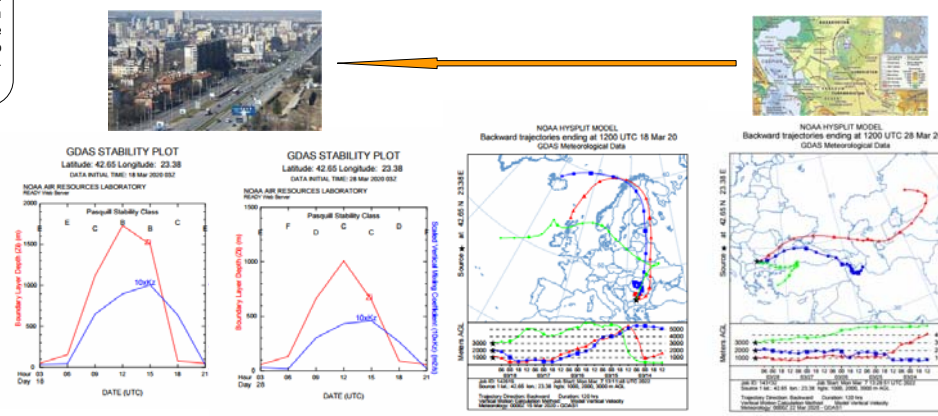

FIGURE 3. Model forecast for Boundary Layer Depth results for Sofia with WRF-GDAS model on 18 March 2020 and 28 March 2020

FIGURE 4. Air mass back-trajectories calculated by the HYSPLIT model ending over Sofia on 18 March 2020 and 28 March 2020

CONCLUSION

The air quality in Sofia was relatively good at the start of the first COVID-19 lockdown in March 2020. This paper presents experimental data at a site near the boulevard "Tsarigradsko shoes" and suggests explanation of the event based on synoptic analysis and trajectory model results. A significant increase of PM10 and PM2.5 concentrations was registered on March 28, 2020 related to transport of dust from the Caspean sea and Karakum desert regions.

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