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Backward trajectories and cluster analyses for study of PM_{10} concentration variations in Bulgarian urban areas

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Abstract: Air pollution with particulate matter (PM) is a serious problem in large urban agglomerations in Bulgaria. The temporal variability of PM concentrations is highly related to the history of the air mass arriving at receptor site. In this study the Trajectory Statistical Methods (TSM) are applied as supplementary tools in identifying the influence of the air mass origin on particulate matter levels in four Bulgarian urban areas (Sofia, Plovdiv, Pleven and Burgas) for 2019. The analysis was made by HYSPLIT model (Hybrid Single-Particle Lagrangian Integrated Trajectory) and statistical software package “Openair” in R. The method of cluster analysis is applied to the back-trajectories data according to the angle, direction and speed of the air mass. The PM_{10} source regions were estimated by the Potential Source Contribution Function (PSCF) and Concentration Weighted Trajectory (CWT) statistical methods. The PM_{10} concentrations in air quality stations in Plovdiv, Pleven, Burgas, Sofia, and some meteorological elements are also presented.

Keywords: PM_{10}, back-trajectories, TSM, cluster analysis, PSCF, CWT

1. INTRODUCTION

Particulate matter (PM) emitted in the atmosphere by natural and anthropogenic sources can be released at one location and travel long range affecting air quality locally and at a long distances away (Salvador et al, 2008, Beverland et al., 2000; Escudero, 2006, Seinfeld and Pandis, 2006). PM_{10} and $PM_{2.5}$ are widely recognized to cause a number of different problems on human health becouse easily inhalation into the respiratory tract, causing inflammatory processes and diseases of the respiratory and cardiovascular systems (Lim et al., 2012; Straif et al, 2013, WHO, 2003) and can affect negatively the

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environment (climate, visibility and biogeochemical cycles) (IPCC, 2001). There are many international actions and collaboration in order to control their levels and effects (EEA, 2018) but the decrease of the PM levels during the last years is still unsatisfactory. About 21% to 41% of the population in Europe is exposed to exceedance of the limit values of PM_{10}, while this number for Bulgaria is 78.6 % (MoEW Report, 2019).

Recently, as useful tool for investigating the sources region of PM is analysis of large number back-trajectories (air masses) arriving at the receptor site (Salvador et al., 2010) by application of trajectory statistical methods (TSM). Those methods allow simultaneous computational treatment of air mass back-trajectories and PM concentrations at one or several receptor points. The use of TSM upon large trajectory ensembles significantly reduce the trajectory uncertainty generated by interpolation and truncation processes, low temporal or spatial resolution of wind data, or an inappropriate selection of the starting heights (Salvador et al., 2010). Many authors have applied TSMs for identifying potential source regions in PM source apportionment studies (Perrone, M.G., et al., 2018; Gunchin G., et al., 2019, Belis C. et al. 2019). Those methods for the first time were applied in Bulgaria on PM_{10} data from city of Plovdiv (Neykova R. & Hristova E., 2020) in a frame of project supported by National Programme "Young scientists and post-doctoral". The extension on this study is presented here.

This work is focused on application of TSM in characterization of source regions and long-range transport episodes which contribute to the daily levels of PM_{10} in the cities Plovdiv, Pleven, Burgas and Sofia for the period 01.01.2019 – 31.12.2019.

2. METHODOLOGY

2.1. The study area

For the study area in this work four cities (Sofia, Plovdiv, Pleven and Burgas) were selected (Figure 1). Two main issues motivated us to choose those cities: 1) air quality problems with high levels of PM's and exceedance of the permitted number of days per year with daily averaged PM_{10} concentrations over 50 $\mu g.m^{-3}$, 2) areas in different part of the country. In the next subsections is given information about every one of the selected cities and for number of air quality stations.

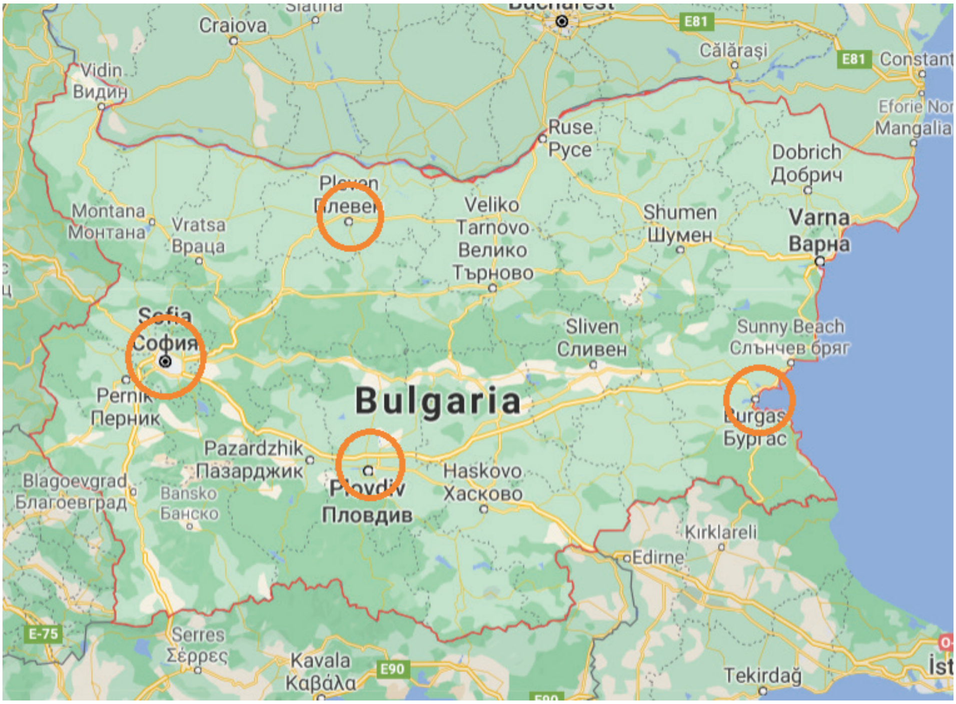


Fig. 1 Map of Bulgaria with study areas/cities

2.1.1. Plovdiv

Plovdiv is a city in Bulgaria placed in the southern part of the Thracian Plain on the banks of the Maritsa River. The Sredna Gora mountain range rise to the northwest, the Chirpan Heights to the east, and the Rhodope mountains to the south. Plovdiv is the second populated city in Bulgaria, with population 347 851 up to 31.12.2019 according National statistical institute of Republic of Bulgaria (URL1). The city has been struggling with poor air quality for years, which mainly results from its location and limited ventilation and also from cumulative impacts of local, regional and transboundary emissions. There are two official air quality stations, part of the National air quality network, named Plovdiv - Kamenitsa (42.142889° N, 24.765239° E) and Plovdiv - zh.k. Trakia (42.141186° N, 24.787952° E). Both sites are in the urban area, but the Kamenitsa is urban background type while zh.k. Trakia is traffic station.

2.1.2. Pleven

Pleven is a city in Central North Bulgaria placed in the middle of the Danube Plain, surrounded by low limestone hills - the Pleven Heights. According to National statistical institute of Republic of Bulgaria the population of the city is about 95 086 up to 31.12.2019 (URL1). There are problems with the poor air quality for years. There is only one official air quality station, part of the National air quality network, named Pleven (43.4118° N, 24.615006° E).

2.1.3.Burgas

Burgas is the biggest city in South-eastern Bulgaria, the second at the Bulgarian seacoast and fourth in the country with population 201 779 up to 31.12.2019 (URL1). Burgas is situated at the westernmost point of the bay by the same name and in the eastern part of the Burgas Plain, in the east of the Upper Thracian Plain. The city is surrounded by the Burgas Lakes: Burgas, Atanasovsko and Mandrensko. Burgas has been struggling with significant air quality problems since the 80s. Up to 1996 there were protests against the ecological situation. There are two official air quality stations, part of the National air quality network in Burgas, named Burgas - kv. Dolno ezerovo (42.518892° N, 27.375144° E) and kv. Meden rudnik (42.456622° N, 27.420967° E). Both sites are in Suburban area, but the kv. Dolno ezerovo is industrial type while kv. Meden rudnik is urban background.

2.1.4. Sofia

Sofia is the capital and largest city of Bulgaria with population 1 242 568 up to 31.12.2019 (URL1). Situated in the central part of western Bulgaria, in the Sofia valley, between Stara Planina to the north-east, Lyulin, Vitosha and Lozen mountains to the south-west, the Vakarel Mountain to the south-east and the low Slivnitsa Heights to the north-west. The problem with the poor air quality is connected with the location of the capital and the limited opportunities of self-cleaning of the atmosphere. For the last few years the main air pollutants in the city are PM’s and nitrogen oxides. In Sofia there are six official air quality stations, part of the National air quality network, named Nadezhda (42.732292° N, 23.310972° E), Hipodruma (42.680558° N, 23.296786° E), Druzhba(42.666508° N, 23.400164° E), Pavlovo (42.669797° N, 23.268403° E), Mladost (42.655488° N, 23.383271° E) and Kopitoto (42.637192° N, 23.243864° E). The stations Nadezhda, Hipodruma, Drujba, Pavlovo and Mladost are in urban area, while Kopitoto is background station, placed on 1345 m altitude.

2.2. PM_{10} and meteorological data

The PM_{10} hourly concentration levels for 2019 obtained at the mentioned air quality monitoring sites of the Executive Environment Agency are used in the statistical analysis. The meteorological data on precipitation amount, wind speed, fog days are received from the NIMH database.

2.3. Back-trajectory analyses

The NOAA (National Oceanic and Atmospheric Administration) HYSPLIT 4.0 model (Air Resources Laboratory 2017) (Stein et al. 2015, Rolph G., et al, 2017) was used to determine the region of origin of the air masses that affect the studied stations. 3-days back-trajectories at 04:00, 12:00 and 18:00 UTC and at 3 different heights above the starting point located at ground level were computed. The weekly archived data GDAS (Global Data Assimilation System) with resolution 1º were used as input. The best procedure to illustrate the vertical structure of the atmosphere is to run trajectories at several heights above the point of interest. 500, 1500 and 2000 m above ground level (agl) have been chosen in this study.

2.4. Trajectory statistical methods (TSM)

Trajectory statistical methods were used as additional instrument for characterization of synoptic situations with increased concentrations in PM levels at the receptor sites. TSM are also helpful in the identification of the potential source areas of the pollution. This analysis contains several steps. Firstly, on the air mass back-trajectories data is performed cluster analysis (CA). Then, the Potential Source Contribution Function (PSCF) and the Concentration Weighted Trajectory (CWT) are calculated. All those functions are applied to the HYSPLIT back-trajectories with the software package “Openair” in R (Carslaw, D. C. and K. Ropkins, 2012, URL2).

2.4.1. Cluster analysis (CA)

Cluster analysis is a statistical method used to examine data and group it into sets of similar data known as clusters. It is a useful method for organizing large data sets into smaller, similar groups. Trajectory coordinates are used as the clustering variables. CA can be used to classify the air mass origins that arrive at a site (Dorling et al., 1992; Brankov et al., 1998; Salvador et al., 2008), but CA does not provide any information on the geographical location of potential source regions. This information can be obtained by using Potential Source Contribution Function.

2.4.2. Potential Source Contribution Function (PSCF)

Potential Source Contribution Function (PSCF) calculates the probability that a source is located at latitude *i* and longitude *j* (Fleming et al.,2012; Pekney et al.,2006).

The basis of PSCF is that if a source is located at *(i,j)*, an air parcel back trajectory passing through that location indicates that material from the source can be collected and transported along the trajectory to the receptor site. PSCF solves

$$PSCF = {}^{m_{ij}}/_{n_{ij}} \tag{1}$$

where n_{ij} is the number of times that the trajectories passed through the cell *(i,j)* and m_{ij} is the number of times that a source concentration was high when the trajectories passed through the cell *(i,j)*. The criterion for determining m_{ij} is controlled by percentile, which is by default 90. Note also that cells with few data have a weighting factor applied to reduce their effect (The openair Project newsletter, 2013).

2.4.3. Concentration Weighted Trajectory (CWT)

Finally, the potential source regions of particles were evaluated by the Concentration Weighted Trajectory (CWT) statistical method, available in the above mentioned "Openair" package computing a concentration field to identify source areas of pollutants (Seibert et al. 1994) by equation 2:

$$C_{ij} = \frac{1}{\sum_{l=1}^{M} \tau_{ijl}} \sum_{l=1}^{M} C_l \, \tau_{ijl} \tag{2}$$

where C_{ij} is the PM concentration, measured in the cell *(i,j)*, *l* is trajectory's index, *M* is the count of all back-trajectories, C_l is the concentration, measured at the receptor site at the time trajectory *l* arrives there, τ_{ijl} is the time spent of the trajectory *l* at the cell *(i,j)*.

For each cell of the grid domain a weighted mean concentration of the pollutant species under study is calculated. The weight for each concentration value of the pollutant's time series is the time spent in that grid cell by the associated trajectory. Areas with high CWT values in the concentration field indicate that, on average, air parcels residing over them resulted in high concentrations of the atmospheric pollutant at the receptor site. Thus, these concentration fields show those potential source areas whose emissions can be transported to the measurement site by prevailing synoptic winds (López, V., et al., 2019)

3. RESULTS AND DISCUSSION

3.1. Particulate matter levels

In this paragraph the daily averaged PM_{10} data for all air quality stations of the selected cities are examined.

3.1.1. Plovdiv

Time series of PM_{10} hourly concentration levels obtained at two air quality monitoring stations (Trakia and Kamenitsa) during the study period are presented in Fig 2. There is a link between the cases of increasing values at the two air quality stations. The exceedance of the 24-h limit value (50 µg.m^{-3}) is observed in both air quality stations during 2019. 93 days are with exceedance in the Trakia station and 66 days for the Kamenitsa station. There are some days with exceedance only in Trakia station (27 days). Most of those days are during the cold period of the year.

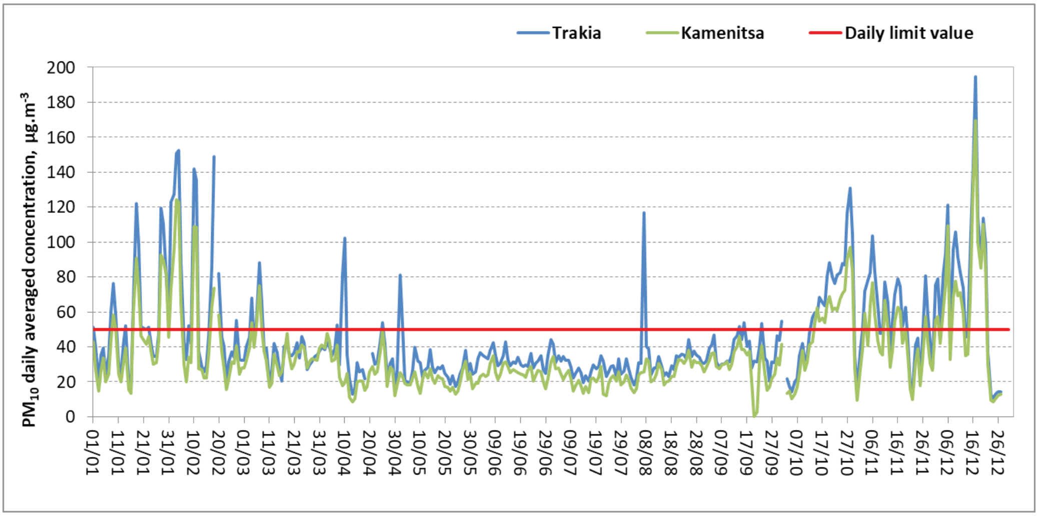


Fig. 2 Time variation of the daily mean PM_{10} values in Plovdiv air quality stations - Trakia and Kamenitsa

The PM_{10} concentrations for the periods with exceedance are between 54.3 and 194.5 $\mu g.m^{-3}$ and from 50.2 to 169.6 $\mu g.m^{-3}$ at Trakia and Kamenitsa station, respectively. 41 days with fog are registered and 298 with precipitation. 63.4% of the precipitation cases are with small amount which is insufficient to be measured (0 mm). The daily averaged wind speed is ranged from 0.3 to 10.5 $m.s^{-1}$.

There are some days with PM_{10} concentration above 50 $\mu g.m^{-3}$ during the warm period of 2019. Very high differences in the PM_{10} concentration between Trakia and Kamenitsa are observed on 11 April, 03 May and 08 August. Probably these cases of exceedance are due to local sources of air pollution.

3.1.2. Pleven

The variations of the daily averaged PM_{10} values measured at the air quality station in Pleven are presented in Fig. 3. During the study period there are 52 exceedances of the daily limit value. Most of them are during the cold part of the year.

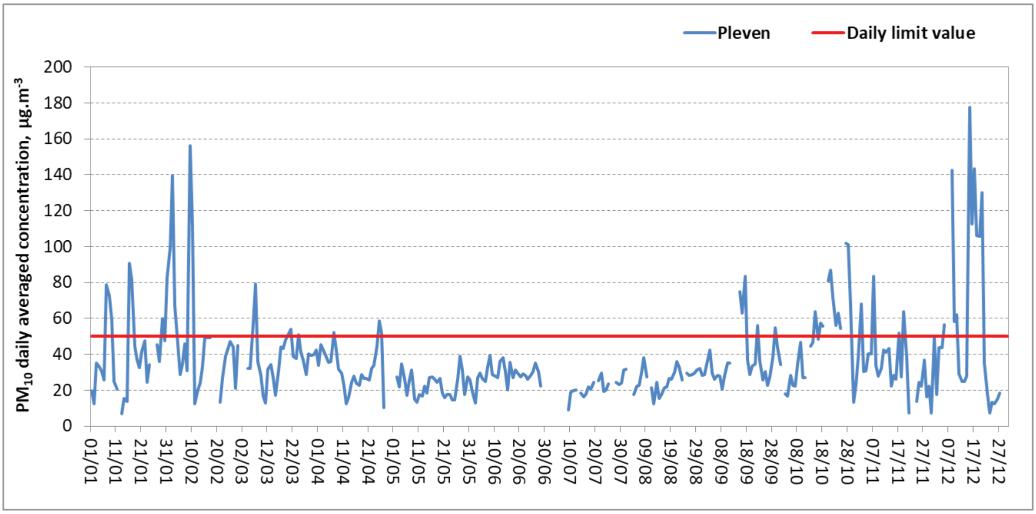


Fig. 3 Time variation of the daily mean PM_{10} values in Pleven air quality station

The PM_{10} concentrations for the periods with exceedance are between 50.9 and 177.6 $\mu g.m^{-3}$. The number of registered days with fog is 39 and 230 days with precipitation. 52.2% of the precipitation cases are with small amount (~ 0 mm). The daily average wind speed was between 0.1 and 11.8 $m.s^{-1}$.

3.1.3. Burgas

Time series of PM_{10} hourly concentration levels obtained at two air quality monitoring stations at Burgas (Meden rudnik and Dolno ezerovo) during the study period are presented in Figure 4. There is no clear link between the cases of elevated PM_{10} concentrations in those stations. Only for 3 days there are exceedances of the 24-h limit value (50 $\mu g.m^{-3}$) at Meden rudnik while at Dolno ezerovo there are 26 days. Most of those cases are during the cold part of the year. The data for the period 26.06 – 17.09 observed at the Meden rudnik air quality station cannot be considered as daily averaged because the observations are not for every hour.

The PM_{10} concentrations for the periods with exceedance are between 51.6 and 181.9 $\mu g.m^{-3}$ and between 50.3 and 462.5 $\mu g.m^{-3}$ at Meden rudnik and Dolno ezerovo stations. 36 days with fog are registered and 255 with precipitation, 60% of them are with small amount (~ 0 mm). The daily averaged wind speed was between 0.6 and 20.5 $m.s^{-1}$.

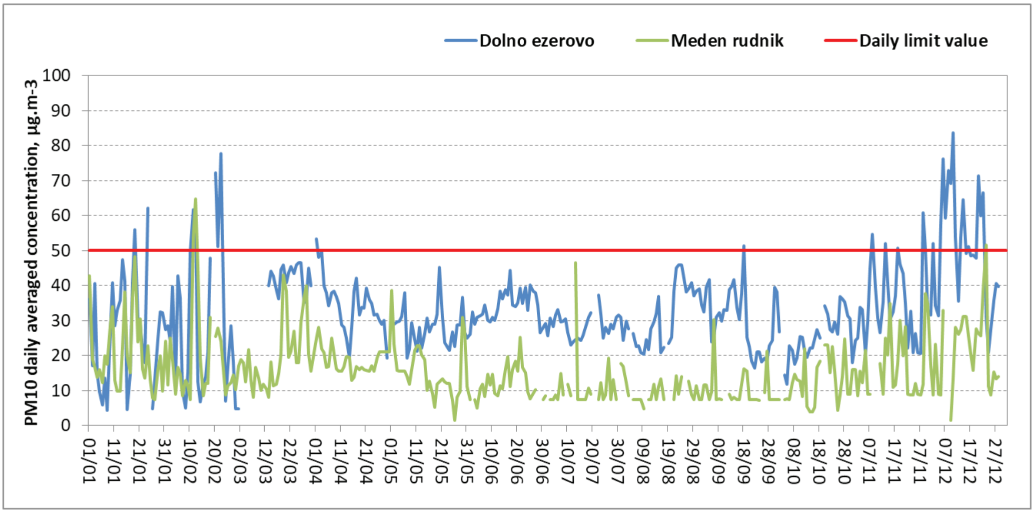
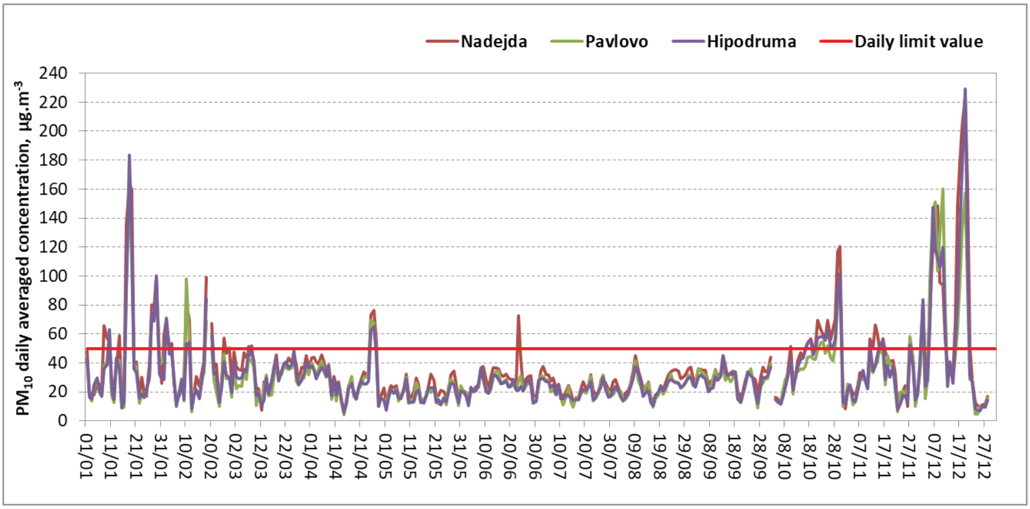


Fig. 4 Time variation of the daily mean PM_{10} values in Burgas air quality stations - Dolno ezerovo and Meden rudnik

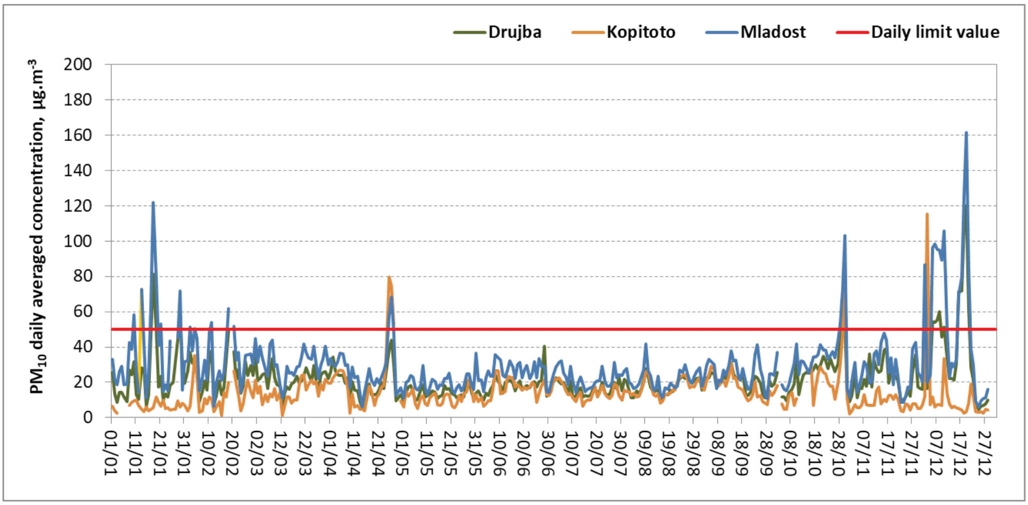
3.1.4. Sofia

Time series of PM_{10} hourly concentrations measured at six air quality monitoring stations in Sofia (Nadezhda, Pavlovo, Hipodruma, Druzhba, Kopitoto and Mladost) are presented in Figure 5a and 5b. There is a clear link between the cases of increasing values at the air quality stations except for the Kopitoto, which is background station and is situated outside the city in the Vitosha Mountain. The exceedance of the 24-h limit value (50µg.m^{-3}) is observed in all air quality stations during 2019. 60 days are with exceedance in the Nadezhda station, 35 days in Pavlovo, 45 in Hipodruma, 15 in Druzhba, 29 in the Mladost station. Most of those cases are during the cold part of the year, but there are some cases during the warm period. There are 5 days with exceedance of the PM_{10} daily limit value for the Kopitoto station – 3 of them are during the spring (probably influenced by Saharan intrusion), the rest are during the cold season.

The PM_{10} concentrations for the periods with exceedance are between 50.1 and 224 µg.m^{-3} at the Nadezhda station, between 50.6 and 160.4 µg.m^{-3} at the Pavlovo station, between 50.8 and 229 µg.m^{-3} at the Hipodruma station, between 51.5 and 120.2 µg.m^{-3} at the Druzhba station, between 52.4 and 115.4 µg.m^{-3} at the Kopitoto station and between 50.6 and 161.5 µg.m^{-3} at the Mladost station. 11 days with fog are registered and 199 with precipitation (37.7% are with very small amount). The daily averaged wind speed is ranged from 0.1 to 4.6 m.s^{-1}.



a)



b)

Fig. 5 Time variation of the daily mean PM_{10} values in Sofia air quality stations – a) Nadezhda, Pavlovo and Hipodruma, b) Druzhba, Kopitoto and Mladost

The number of days with exceedance of the PM_{10} daily limit value of the range of PM_{10} concentration, wind speed range, and the range of precipitation amount for all chosen receptor stations for the period 01.01-31.12.2019 are summarised in Table 1.

Table 1. Number of days (N) with of PM_{10} > 50 μg.m^{-3}, PM_{10} concentration range, wind speed range and precipitation amount range for the period 01.01-31.12.2019

City/Station	N	PM_{10} range μg.m^{-3}	Wind speed range* (m.s^{-1})	Precipitation amount range* (mm)
Plovdiv/Trakia	93	10.9 - 194.5	0 - 18	0** - 79.3
Pleven	52	6.9 - 177.6	0 - 20	0** - 54.8
Burgas/ Dolno ezerovo	28	4.3 - 83.6	0 - 24	0** - 39.8
Sofia/Mladost	29	6 - 161.5	0 - 10	0** - 30.7

*- measured at NIMH stations

**- small amount of precipitation which is insufficient to be measured

3.2. TSM results

A total of 13140 backward trajectories were obtained ending at 04:00, 12:00 and 18:00 UTC hours for each day in Trakia station (Plovdiv), Pleven, Dolno ezerovo (Burgas) and Mladost (Sofia) of the studied period 1.01.-31.12.2019. The calculations were at 3 different heights (500, 1500, 2000 m agl). They have been clustered using “Openair” to establish the different air-flow patterns. Five typical meteorological synoptic situations (clusters) were obtained.

The comparison of obtained clusters, PSCF and weighted mean PM_{10} concentration for level 2000m are presented in Figures 6-9, for Plovdiv, Pleven, Burgas and Sofia, respectively.

The comparison of the cluster analysis at the 3 heights (500, 1500 and 2000 m agl) for the four starting locations shows some similarities, but some differences also. The differences are due to the predominant air masses, because of the location of the starting points. Station Burgas is located at the seacoast, Pleven is in the central part of the Danube Plain, and Plovdiv is in the central part of southern Bulgaria, while Sofia is in the central western part of the country.

Cluster 1 (C1) at level 500 m agl is from north-west in Plovdiv and Sofia, about 30% in both stations, while in Pleven is from north (13.5%) and from east in Burgas (32.7%). Cluster 2 (C2) is with north component in the four stations (about 22-31%), but in Pleven there is also west component and in Sofia – east. In Plovdiv and Pleven Cluster 3 is coming from south-west (~18%), but in Burgas is from north-west (20.8%) and in Sofia is from west (12.1%). Cluster 4 (C4) is from south in Plovdiv (9.2%) and in Pleven (12.9%), while in Sofia and Burgas is from south-west and is between 12-15%. Cluster 5 in Plovdiv and Pleven is from east (20.5 and 24.8%), in Burgas and Sofia is from south (7.3 and 15.4% respectively)

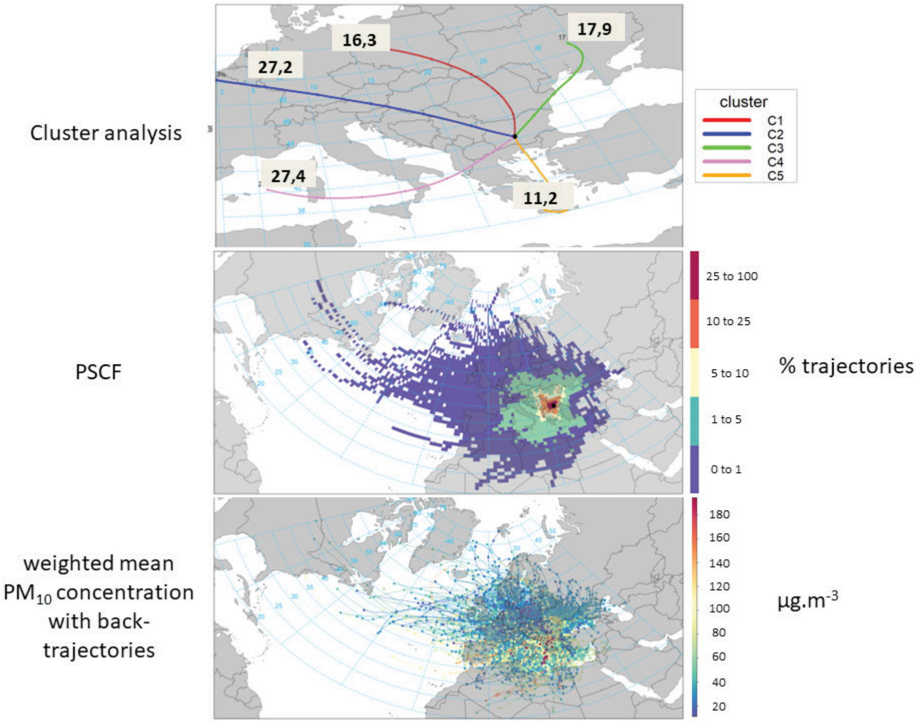


Fig. 6. Cluster analysis, PSCF and weighted mean PM_{10} concentration with back-trajectories for Plovdiv

Cluster 1 (C1) at level 1500 m agl is from north in Plovdiv (13.8%) and Pleven (12.4%), from north-west in Burgas with 21.1% and from north-east in Sofia with 23.1%. Cluster 2 (C2) has north component in all 4 stations, but only in Burgas is pure north (14.3%), while in the other stations there is west component also and is about 21-28%. In Pleven and Burgas Cluster 3 (C3) is from west ~25%, in Plovdiv is from north-east (19.5%) and in Sofia – north-west with 21.5%. About 20 % and from east is Cluster 4 (C4) in Pleven and Burgas, while in Plovdiv is from west (26.6%) and in Sofia is from north-west (21.4%). Cluster 5 (C5) in Plovdiv, Pleven and Sofia is from south between 13-15%, while in Burgas is from south-west and about 20%.

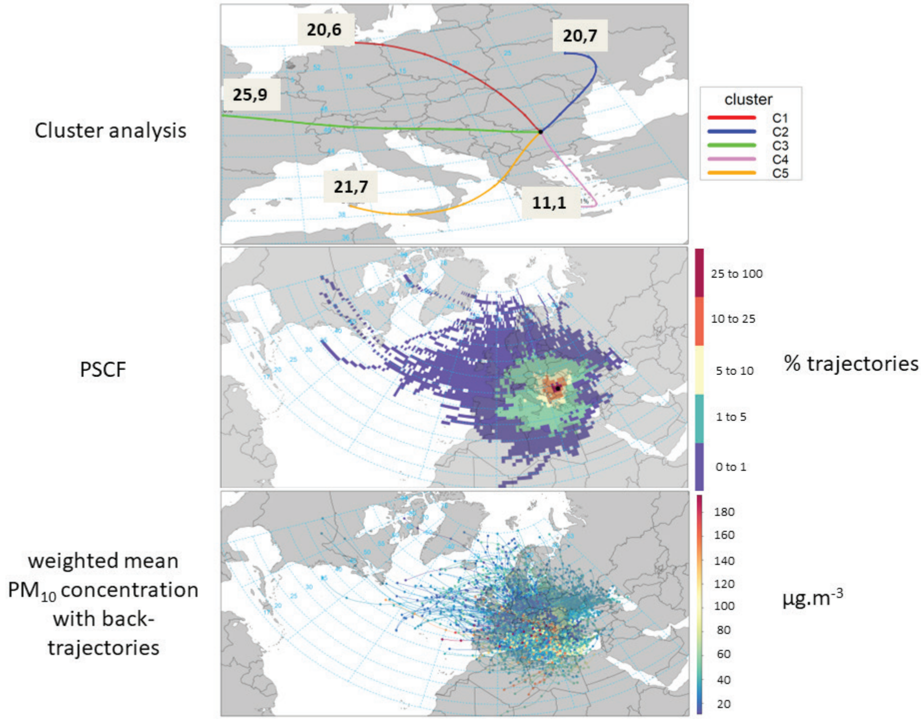


Fig. 7. Cluster analysis, PSCF and weighted mean PM_{10} concentration with back-trajectories for Pleven

Level 3 (2000 m agl) is quite similar to level 2 (1500 m agl). The differences are that Cluster 1 in Burgas has changed its direction from north-west to north. Cluster 2 in Pleven at level 3 is from north-east, in Burgas – from north-west. In Burgas Cluster 3 is from east. Cluster 4 is from south in Plovdiv and Pleven, while in Burgas - south-west. Cluster 5 in Plovdiv and Pleven is orientated from south-west at level 3, while in Burgas - south. In Sofia the direction stays the same as in level 2.

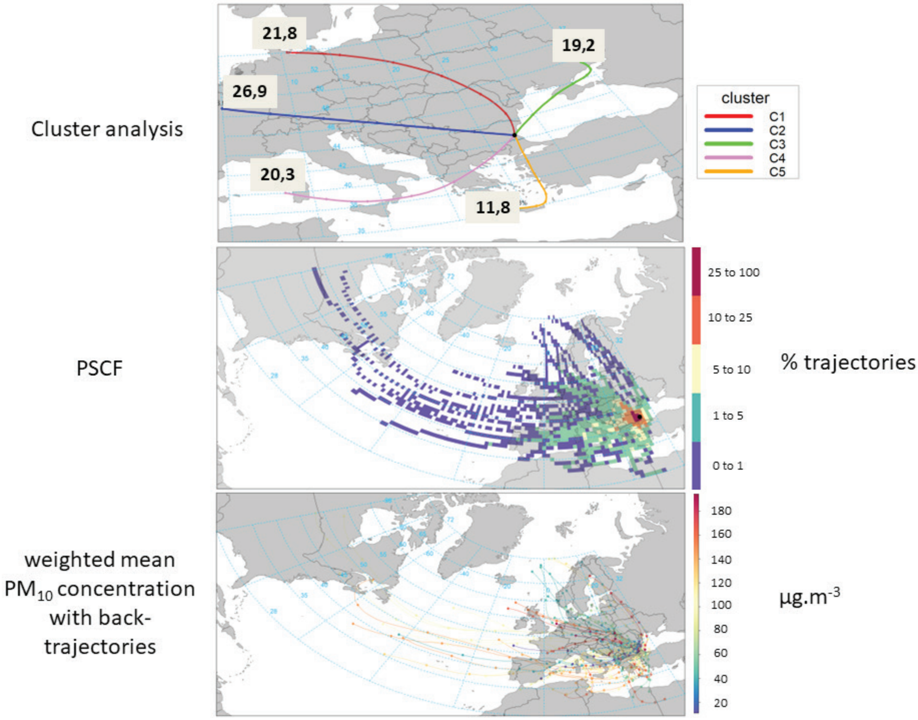


Fig. 8. Cluster analysis, PSCF and weighted mean PM_{10} concentration with back-trajectories for Burgas

PSCF frequency maps indicate the geographic origin of the air masses that reach the study site. The PSCF analysis for the 3 studied levels presents prevailing percentage of air mases south - south-west in Pleven and Sofia, west – north-west in Plovdiv and north – north-east in Burgas.

The CWT analysis is made in order to have the PM_{10} concentrations for every one of the trajectories. The results are reported on geographical maps. For each cell of any map a weighted concentration of the PM was computed.

Information about the results for averaged concentrations of PM_{10} for all stations is given in Table 2. The lowest concentrations of PM_{10} in Plovdiv are obtained during periods with air masses from south (C4 at levels 1 and 3 and C5 at level 2) and the highest – from north-west (C1 at level 1 and C2 at level 2). The lowest concentrations in Pleven are obtained during air flows from south (C4 at levels 1 and 3) and highest – from north-west (C2 at levels 1 and 2). In Burgas during flows from south are registered the lowest average PM_{10} concentrations (C5 at levels 1 and 3), while the highest are changing with the height – starting with east at level 1 (C1), going west at level 2 (C3) and goes to north-west (C2) at level 2000 m agl. The air mases from north-west (C1 at level 1 and C2 at level 3) contribute to the highest measured concentrations of PM_{10} in Sofia, while the lowest are during flows from south (C5 at levels 2 and 3).

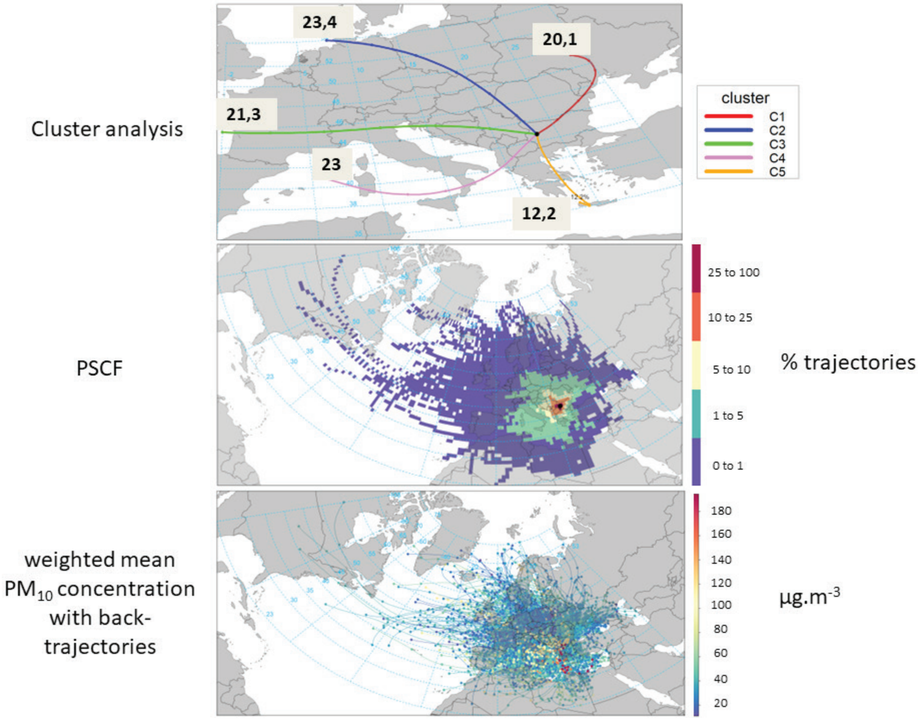


Fig. 9. Cluster analysis, PSCF and weighted mean PM_{10} concentration with back-trajectories for Sofia

Information about the results for averaged concentrations of PM_{10} for all stations is given in Table 2. The lowest concentrations of PM_{10} in Plovdiv are obtained during periods with air masses from south (C4 at levels 1 and 3 and C5 at level 2) and the highest – from north-west (C1 at level 1 and C2 at level 2). The lowest concentrations in Pleven are obtained during air flows from south (C4 at levels 1 and 3) and highest – from north-west (C2 at levels 1 and 2). In Burgas during flows from south are registered the lowest average PM_{10} concentrations (C5 at levels 1 and 3), while the highest are changing with the height – starting with east at level 1 (C1), going west at level 2 (C3) and goes to north-west (C2) at level 2000 m agl. The air mases from north-west (C1 at level 1 and C2 at level 3) contribute to the highest measured concentrations of PM_{10} in Sofia, while the lowest are during flows from south (C5 at levels 2 and 3).

Table 2. Mean PM_{10} concentration ($\mu g.m^{-3}$) by trajectory cluster at 3 different levels

	Plovdiv		
	Level 500	Level 1500	Level 2000
Cluster 1	36 (NW)	38.3 (N)	35.6 (N)
Cluster 2	37.7 (N)	36.3 (NW)	38 (NW)
Cluster 3	64.4 (SW)	40 (NE)	40.4 (NE)
Cluster 4	58.1 (S)	58.5 (W)	57.7 (S)
Cluster 5	44.4 (E)	52.5 (S)	55.1 (SW)
	Pleven		
	Level500	Level 1500	Level 2000
Cluster 1	33.7 (N)	36.1 (N)	30.4 (N)
Cluster 2	29.6 (NW)	29.6 (NW)	32.9 (NE)
Cluster 3	53.4 (SW)	46.1 (W)	36.4 (W)
Cluster 4	40.8 (S)	32 (E)	39.8 (S)
Cluster 5	34.2 (E)	42.8 (S)	46.6 (SW)
	Burgas		
	Level500	Level 1500	Level 2000
Cluster 1	32.6 (E)	33.7 (NW)	33.7 (N)
Cluster 2	34.9 (N)	30.5 (N)	30.5 (NW)
Cluster 3	31 (NW)	35.7 (W)	35.7 (E)
Cluster 4	40.2 (SW)	33.6 (E)	33.6 (SW)
Cluster 5	37.1 (S)	36.8 (SW)	36.8 (S)
	Sofia		
	Level500	Level 1500	Level 2000
Cluster 1	25.3 (NW)	27 (NE)	27.2 (NE)
Cluster 2	25.8 (NE)	23.1 (NW)	23.5 (NW)
Cluster 3	33.7 (W)	31 (NW)	31.3 (W)
Cluster 4	39.2 (SW)	37.2 (SW)	34.4 (SW)
Cluster 5	36.8 (S)	31.9 (S)	35.3 (S)

3. CONCLUSIONS

In this study the trajectories statistical methods have been applied to a set of 1 year back-trajectories in order to describe the main flow patterns in four Bulgarian cities: Plovdiv, Pleven, Burgas and Sofia and for identification of geographical region for remote PM sources. The Cluster analysis (CA), Potential Source Contribution Function (PSCF) and Concentration Weighted Trajectory (CWT) were used for the first time on PM_{10} data from Bulgarian urban air quality stations. Air mass back-trajectories were grouped into 5 clusters, representing a typical meteorological scenario. The results from PSCF and CWT analyses present possible influence on daily PM_{10} concentrations from cross-border natural and anthropogenic sources, mainly from south, south-west for all cities.

The obtained results are a step towards scientifically based studies on identifying different source regions of different air pollutants in Bulgaria. More studies on seasonality pattern are needed. Further studies on combining observations on PM chemical composition and Trajectory Statistical Methods are planned.

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