



# Backward trajectories and cluster analyses for study of PM10 concentration in Bulgaria during dust episodes

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- *Rozeta Neykova and Elena Hristova, BACKWARD TRAJECTORIES AND CLUSTER ANALYSES FOR STUDY OF PM10 CONCENTRATION IN BULGARIA DURING DUST EPISODES, BJMH, Volume 25, Number 2*



# Outline

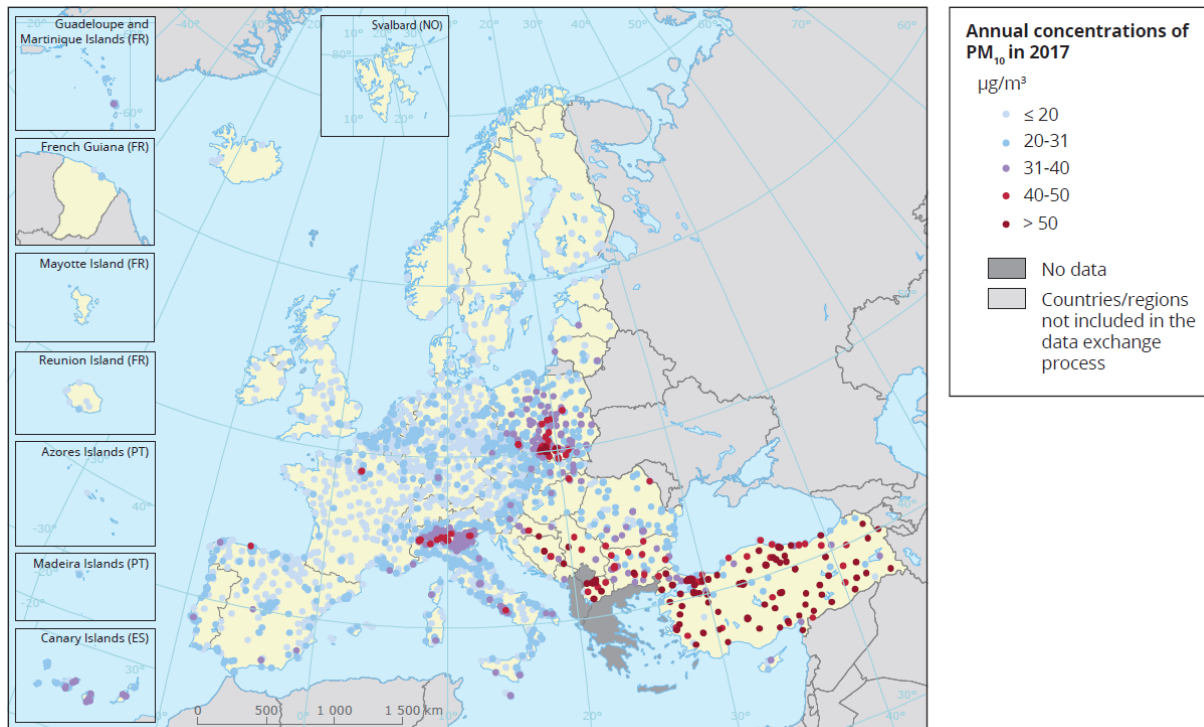
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- Air pollution with Particulate Matter
- Dust episodes
- Methodology
- Results
- Conclusion



# Air pollution with Particulate Matter

- Concentrations of particulate matter (PM) continued to exceed the EU limit values and the WHO AQGs in large parts of the Europe
- PM<sub>10</sub> concentrations above the EU daily limit value were registered at 22 % of the reporting stations (646 out of 2 886) in EU Member States (EU-28)
- A total of 17 % of the EU-28 urban population was exposed to PM<sub>10</sub> levels above the daily limit value and 44 % was exposed to concentrations exceeding the stricter WHO AQG value for PM<sub>10</sub>.

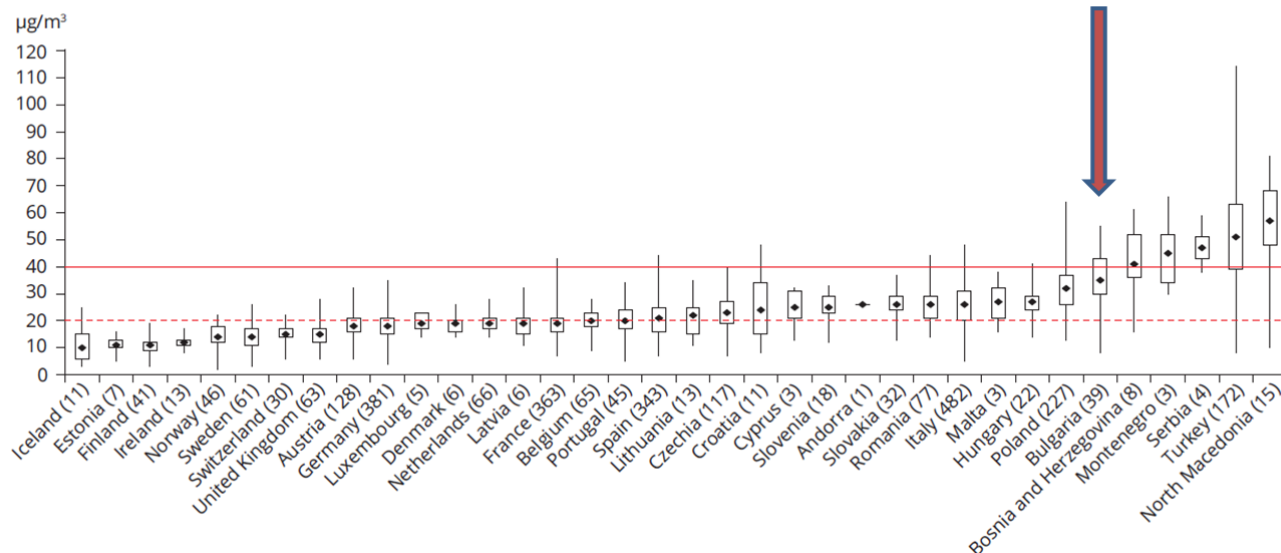




# Motivation and Objectives

- Air Pollution with PM remains a **serious problem** in large urban agglomerations in Bulgaria
- The temporal variability of atmospheric particulate matter (PM) concentrations at a monitoring site is highly related to the **history of the air mass** arriving at that site

PM<sub>10</sub> concentrations in relation to the annual limit value in 2017 and number of stations considered for each country



<https://www.eea.europa.eu/publications/air-quality-in-europe-2019>

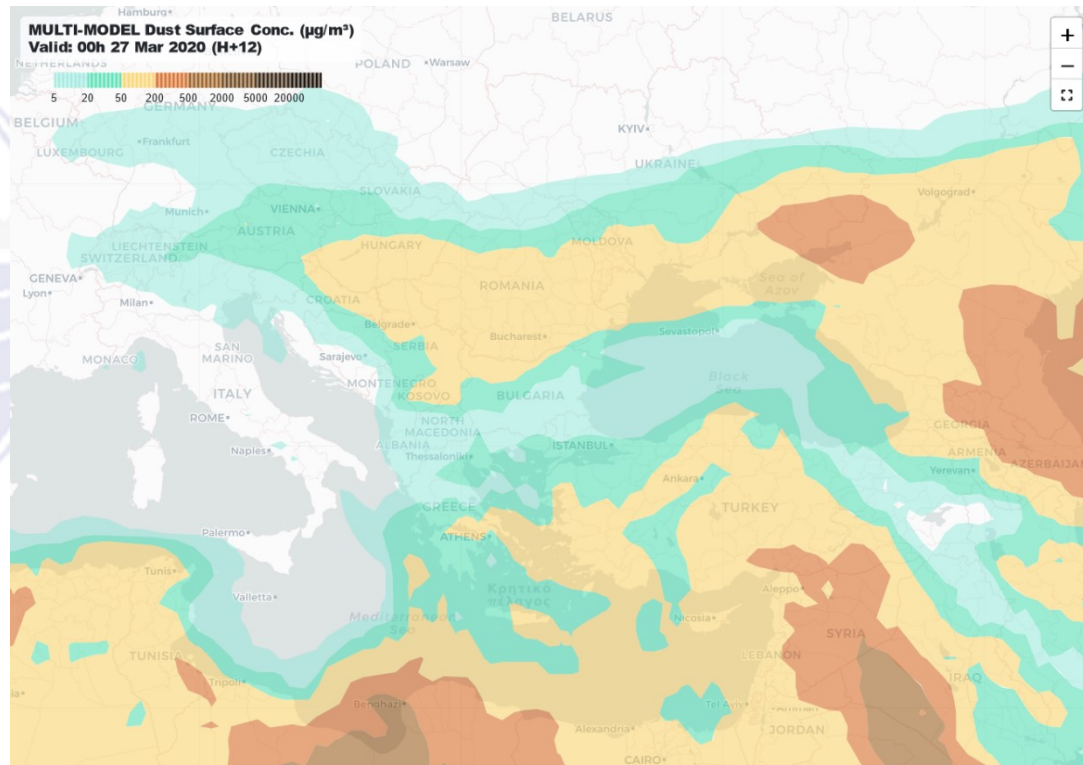
The main objective - to study the influence of the origin of air mass at a synoptic scale on PM levels at urban air quality monitoring stations.



# Dust episodes

## Barcelona Dust Forecast Center

- Regional Specialized Meteorological Center with activity specialization on Atmospheric Sand and Dust Forecast - RSMC-ASDF.
- Manages and coordinates the research activities and operations of the World Meteorological Organization (WMO) related to sand and dust storms.
- The Center provides access to available dust products and coordinates a network of collaborators in Northern Africa, the Middle East and Europe.





# The study area

- Rojen and Plovdiv, southern Bulgaria
- Kopitoto and Sofia, south-west Bulgaria
- **PM<sub>10</sub> hourly data** from the official air quality stations at National air quality network for the cases with forecasted dust episodes for the period 2019-2020 according to the Barcelona dust forecast center



- *Red dots - Sofia and Plovdiv*
- *Green dots - Rojen and Kopitoto, background stations*

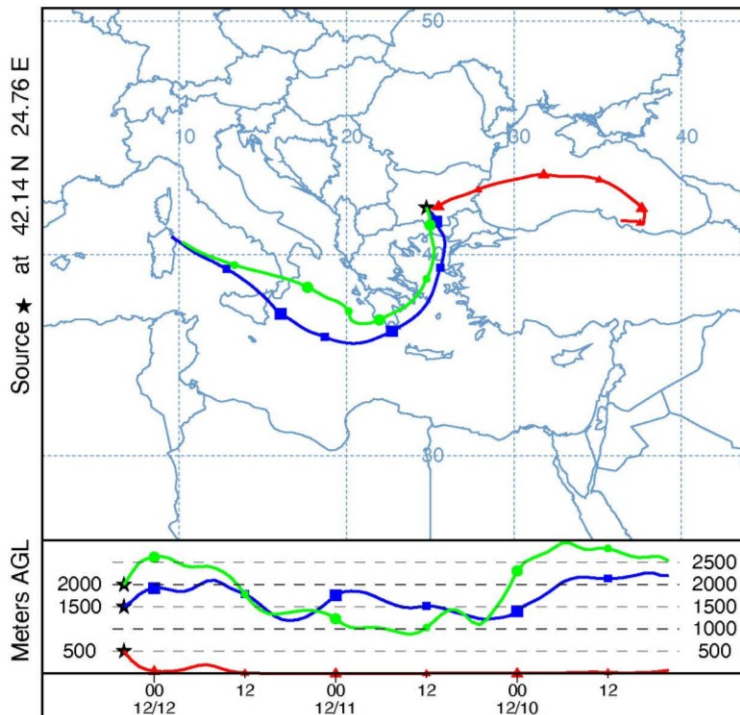


# Back-trajectories

## The Hybrid Single-Particle Lagrangian Integrated Trajectory model (HYSPLIT) (<http://www.ready.noaa.gov>)

The HYSPLIT model is a complete system for computing simple air parcel trajectories, as well as complex transport, dispersion, chemical transformation, and deposition simulations.

NOAA HYSPLIT MODEL  
Backward trajectories ending at 0400 UTC 12 Dec 19  
GDAS Meteorological Data



- 3-days (72 h) back-trajectories at 04:00, 12:00 and 18:00 UTC
- 3 different heights 500, 1500 and 2000 m AGL
- GDAS met data 1° resolution

**A total 6183 backward trajectories**





# Trajectory statistical methods (TSM)

TSM can help us to:

- Characterize synoptic meteorological situations which give rise to low and high concentration levels of PM at a receptor site
- Identify potential source regions of PM which can be transported towards the sampling site

TSM were applied to the HYSPLIT back-trajectories with the software package “Openair” in R

## Cluster analysis

- Statistical method used to examine data and group it into sets of similar data known as clusters.

## Potential Source Contribution Function

- Calculates the probability that a source is located at latitude  $i$  and longitude  $j$

$$\bullet PSCF = m_{ij} / n_{ij}$$

## Concentration Weighted Trajectory (CWT)

- The weight for each concentration value of the pollutant's time series is the time spent in that grid cell by the associated trajectory

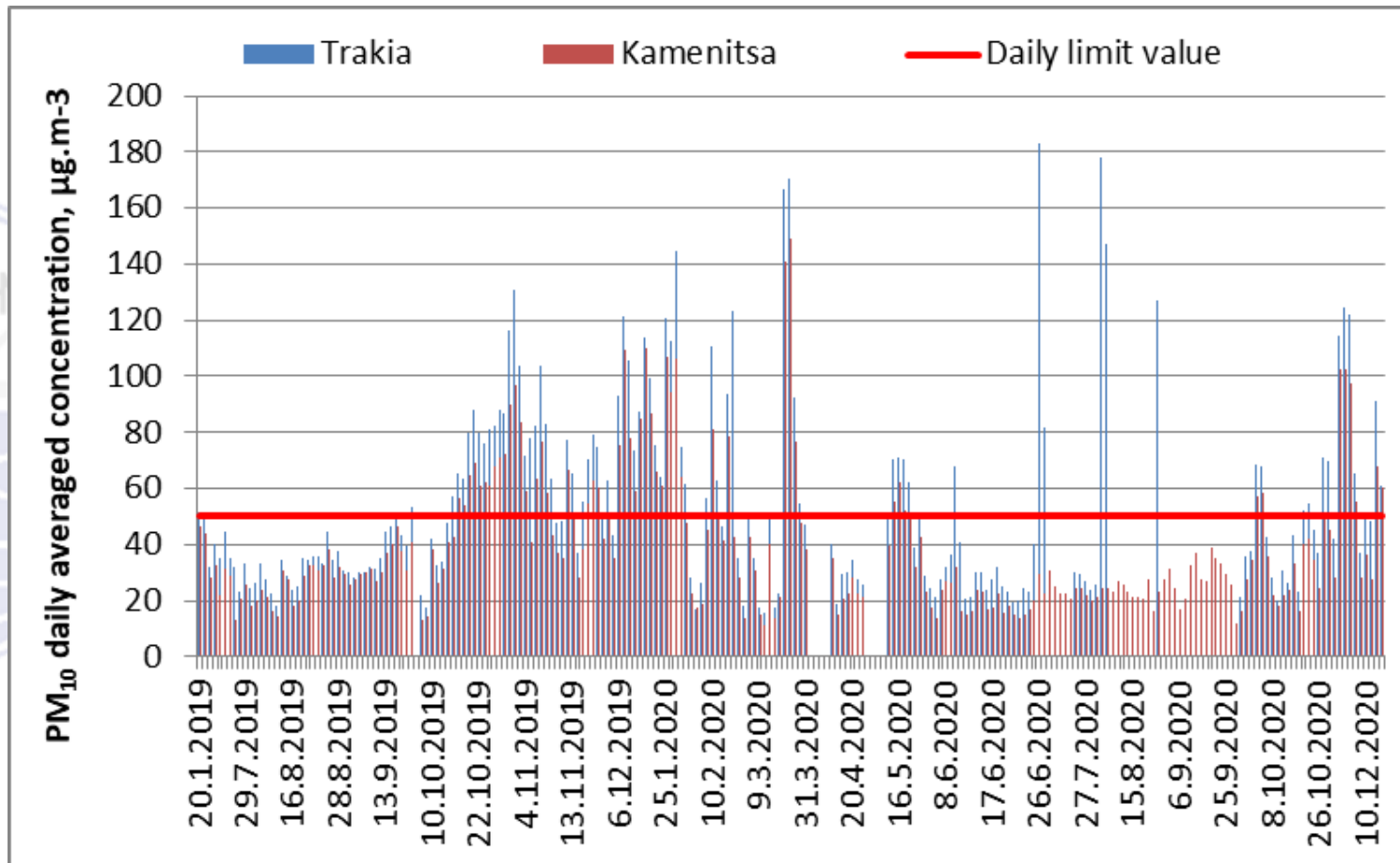
$$\log \bar{C}_{ij} = \frac{\sum_{l=1}^m n_{ijl} \log C_l}{\sum_{l=1}^m n_{ijl}}$$



# PM<sub>10</sub> daily averaged concentration levels

Exceedance of the 24-h limit value (50  $\mu\text{g}\cdot\text{m}^{-3}$ ):

- Trakia station – **79** days
- Kamenitsa station - **53** days

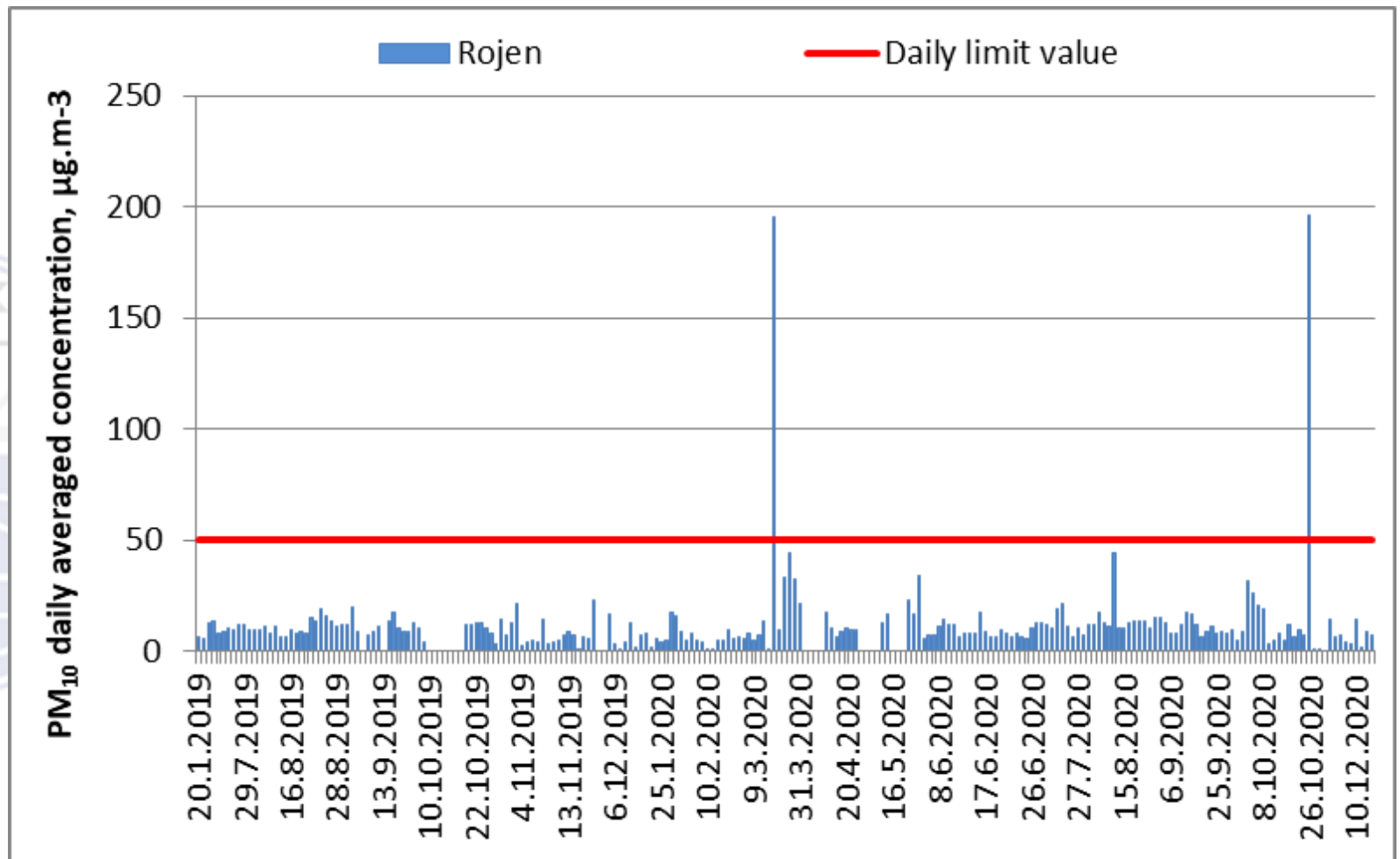




# PM<sub>10</sub> daily averaged concentration levels

Exceedance of the 24-h limit value (50  $\mu\text{g}\cdot\text{m}^{-3}$ ):

➤ Rojen station - **2** days

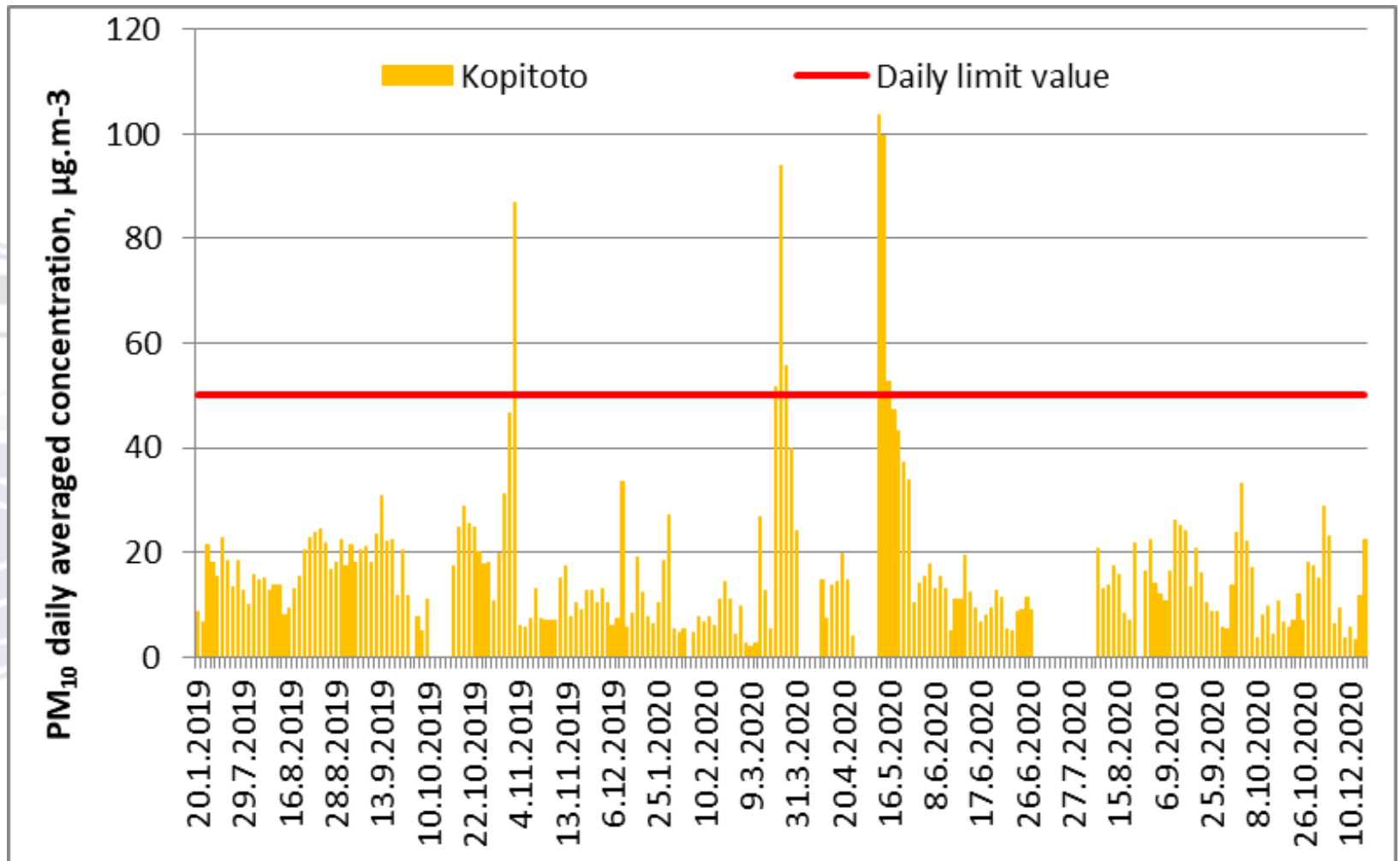




# PM<sub>10</sub> daily averaged concentration levels

Exceedance of the 24-h limit value (50  $\mu\text{g}\cdot\text{m}^{-3}$ ):

➤ Kopitoto station - **7** days

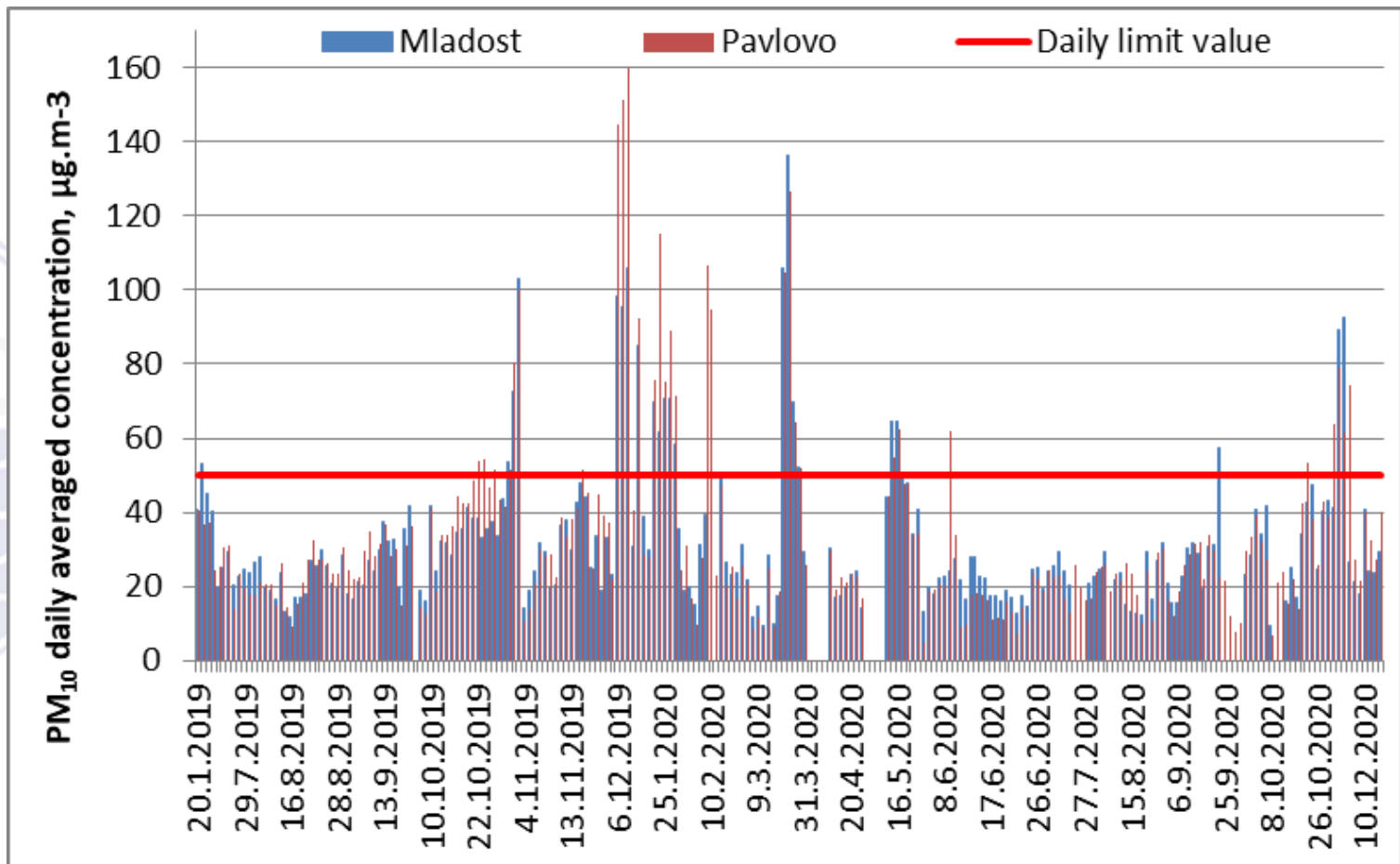




# PM<sub>10</sub> daily averaged concentration levels

Exceedance of the 24-h limit value (50  $\mu\text{g}\cdot\text{m}^{-3}$ ):

- Mladost station - **23** days
- Pavlovo station - **30** days





# Maximal, minimal and average daily concentration of PM<sub>10</sub> (μg.m<sup>-3</sup>) at the air quality stations for the study period

Station	min	max	mean
Trakia	15.71	183.12	54.42
Kamenitsa	11.38	149.32	38.98
Rozhen	0.33	196.36	12.35
Mladost	9.57	136.16	31.87
Pavlovo	5	160.02	32.88
Kopitoto	1.97	103.74	16.66

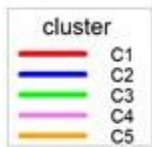


# TSM results

weighted mean  $PM_{10}$   
concentration with back-  
trajectories

Latitude

PSCF



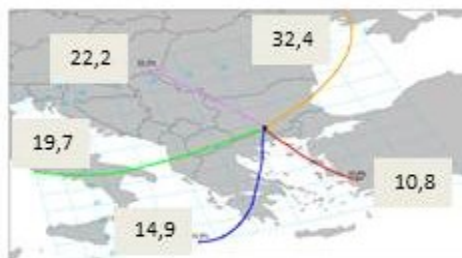
Plovdiv



% trajectories



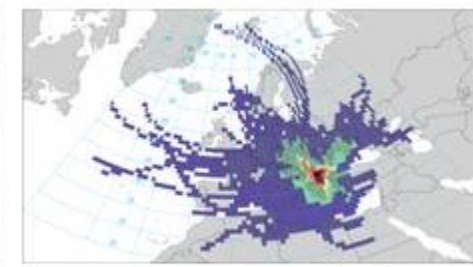
Rozhen



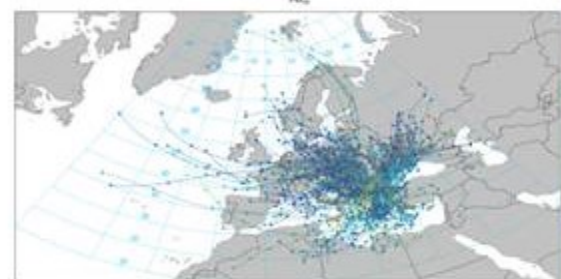
10 to 25



Sofia



1 to 5



0 to 1

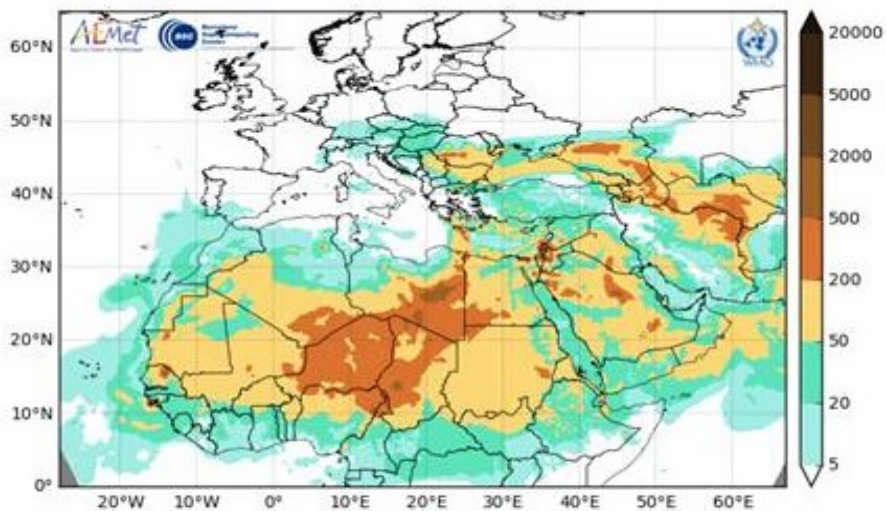
Longitude

Level 500 m

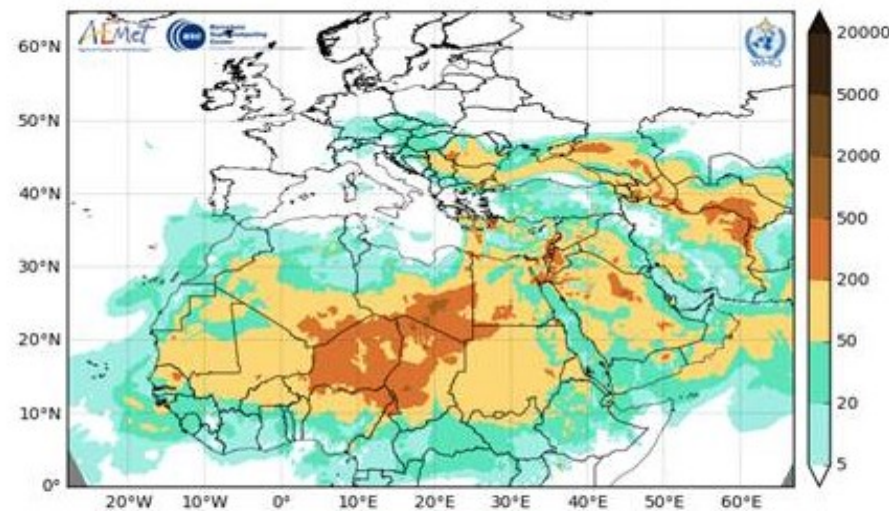


# Case study – 27.03.2020

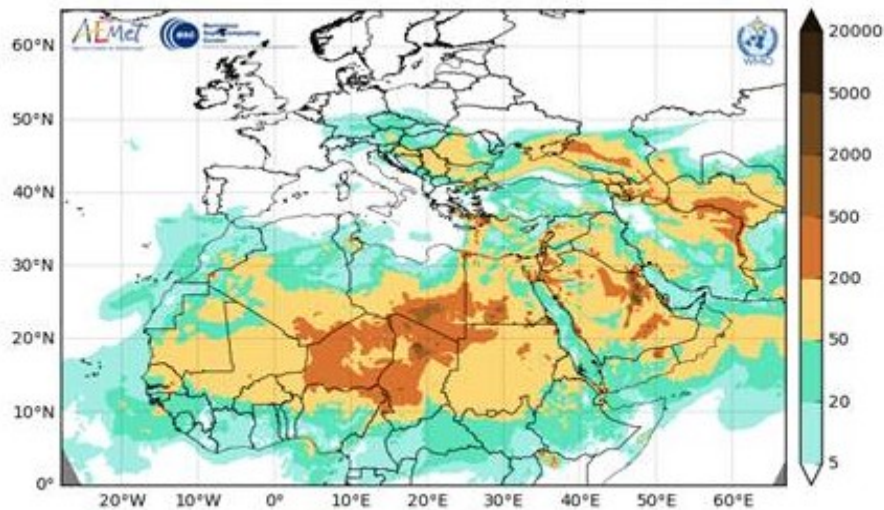
Barcelona Dust Forecast Center - <http://dust.aemet.es/>  
NMMB-MONARCH Res:0.1°x0.1° Dust Surface Conc. ( $\mu\text{g}/\text{m}^3$ )  
Run: 12h 26 MAR 2020 Valid: 00h 27 MAR 2020 (H+12)



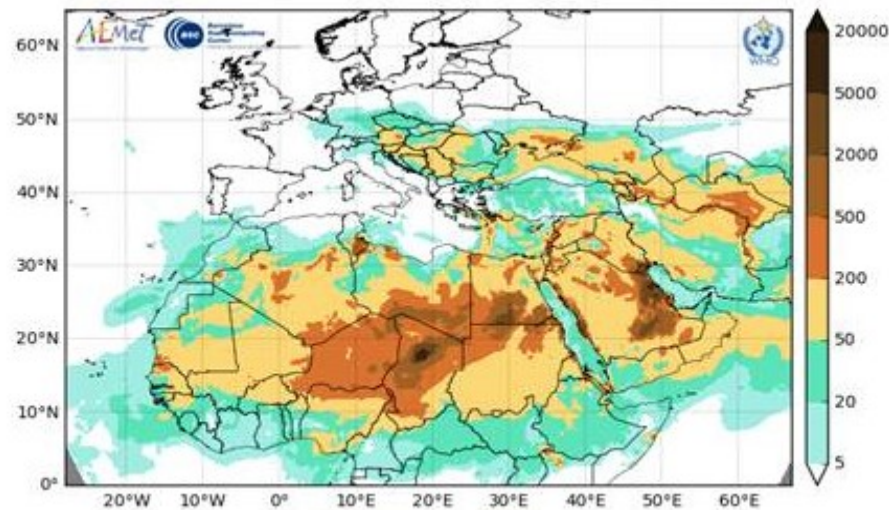
Barcelona Dust Forecast Center - <http://dust.aemet.es/>  
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Run: 12h 26 MAR 2020 Valid: 03h 27 MAR 2020 (H+15)



Barcelona Dust Forecast Center - <http://dust.aemet.es/>  
NMMB-MONARCH Res:0.1°x0.1° Dust Surface Conc. ( $\mu\text{g}/\text{m}^3$ )  
Run: 12h 26 MAR 2020 Valid: 06h 27 MAR 2020 (H+18)



Barcelona Dust Forecast Center - <http://dust.aemet.es/>  
NMMB-MONARCH Res:0.1°x0.1° Dust Surface Conc. ( $\mu\text{g}/\text{m}^3$ )  
Run: 12h 26 MAR 2020 Valid: 09h 27 MAR 2020 (H+21)

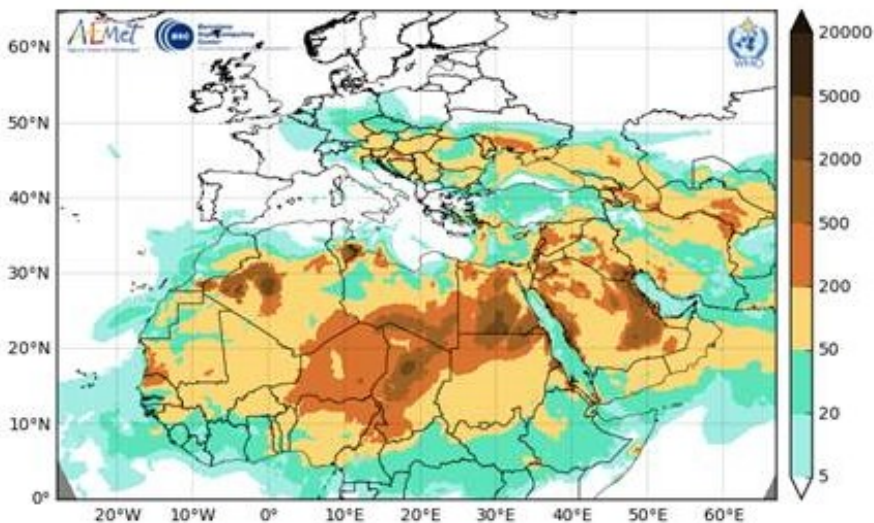




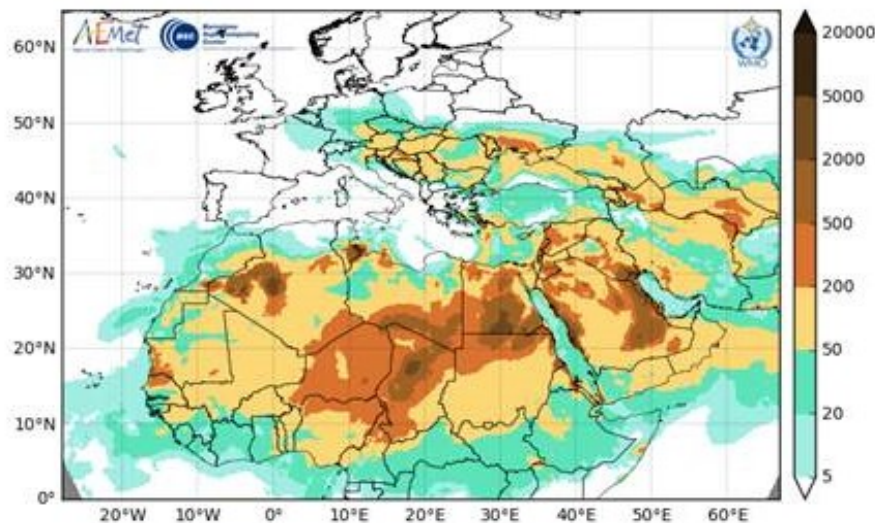


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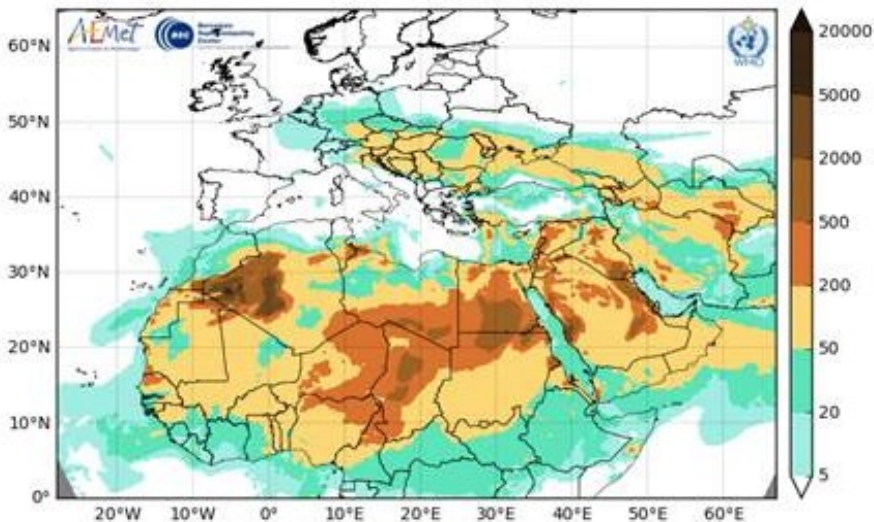
Barcelona Dust Forecast Center - <http://dust.aemet.es/>  
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Run: 12h 26 MAR 2020 Valid: 12h 27 MAR 2020 (H+24)



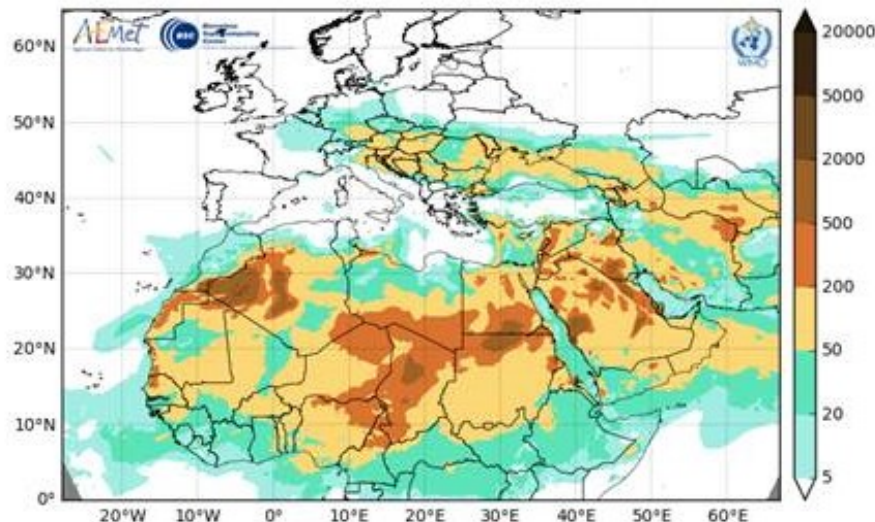
Barcelona Dust Forecast Center - <http://dust.aemet.es/>  
NMMB-MONARCH Res:0.1°x0.1° Dust Surface Conc. ( $\mu\text{g}/\text{m}^3$ )  
Run: 12h 27 MAR 2020 Valid: 12h 27 MAR 2020 (H+00)



Barcelona Dust Forecast Center - <http://dust.aemet.es/>  
NMMB-MONARCH Res:0.1°x0.1° Dust Surface Conc. ( $\mu\text{g}/\text{m}^3$ )  
Run: 12h 27 MAR 2020 Valid: 15h 27 MAR 2020 (H+03)



Barcelona Dust Forecast Center - <http://dust.aemet.es/>  
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Run: 12h 27 MAR 2020 Valid: 18h 27 MAR 2020 (H+06)



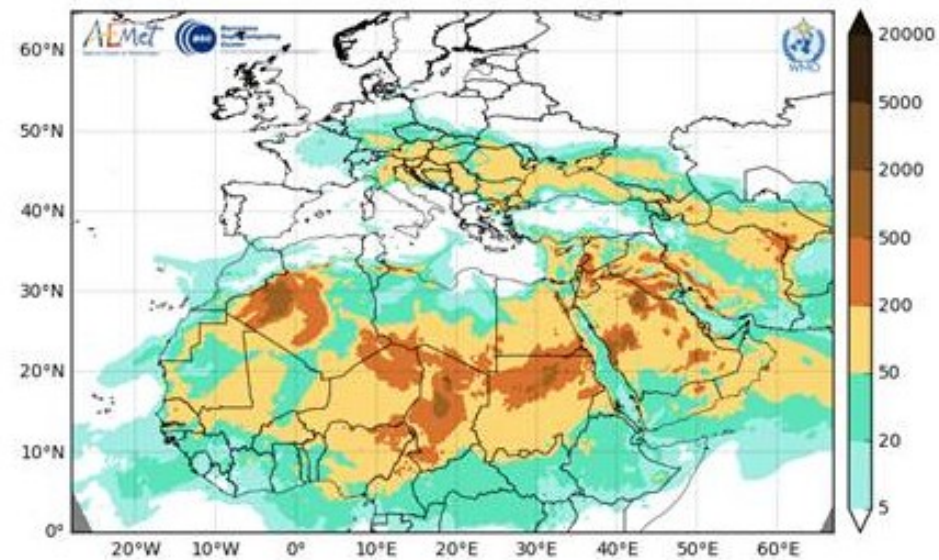
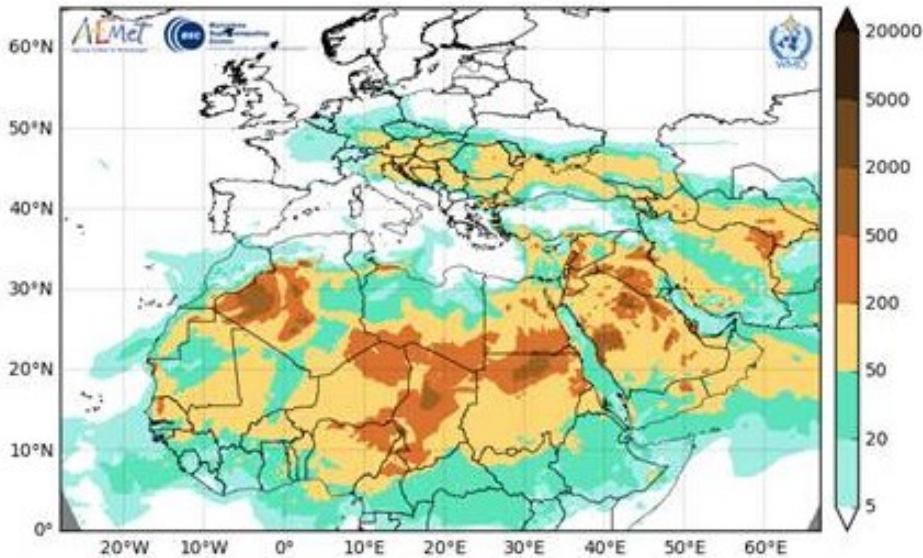




# Case study – 27.03.2020

Barcelona Dust Forecast Center - <http://dust.aemet.es/>  
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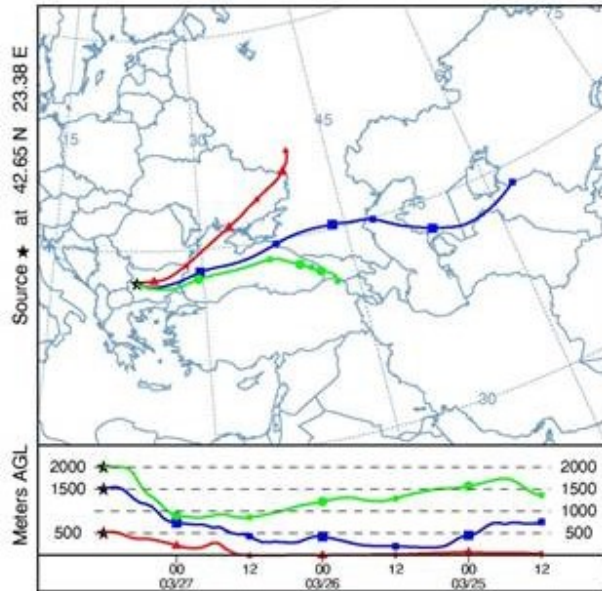
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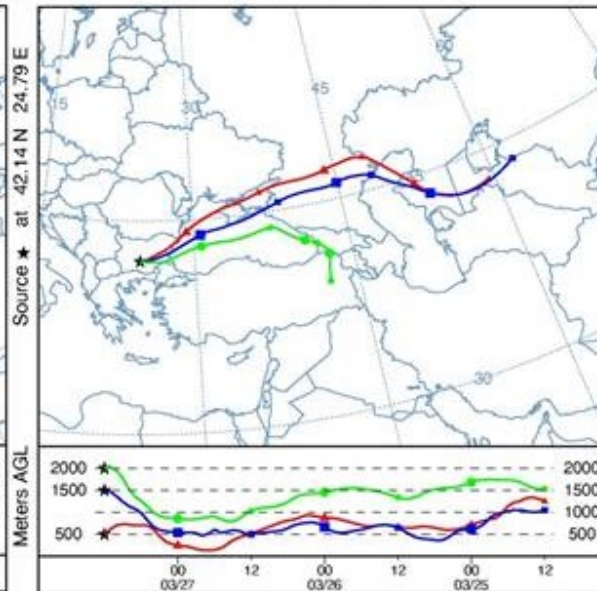


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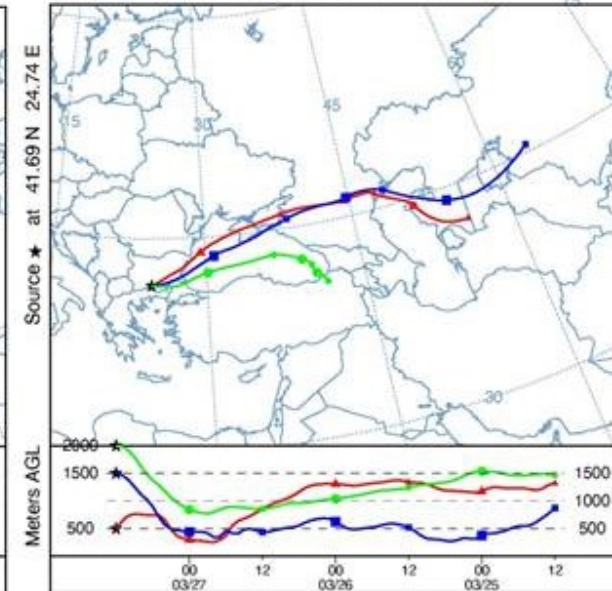
NOAA HYSPLIT MODEL  
Backward trajectories ending at 1200 UTC 27 Mar 20  
GDAS Meteorological Data



NOAA HYSPLIT MODEL  
Backward trajectories ending at 1200 UTC 27 Mar 20  
GDAS Meteorological Data



NOAA HYSPLIT MODEL  
Backward trajectories ending at 1200 UTC 27 Mar 20  
GDAS Meteorological Data





# Conclusions

- Application of back trajectories and TSMs for forecasted dust episodes according to the Barcelona Dust Forecast Center for 2 years (2019 and 2020).
- Air mass back-trajectories were grouped into **5 clusters**, representing a typical meteorological scenario during dust episodes in Bulgaria.
- The results from CA, PSCF and CWT analyses present possible cross-border natural and anthropogenic dust transportation, influencing on daily PM10 concentrations, coming from east direction mainly with possible origin from the North African or from the Middle East.
- The application of Trajectory Statistical Methods as a supplementary tool **can be very useful** in studies aimed to characterize sources and formation processes of PM.
- Combining these methods with the PM chemical composition would give more detailed information about the origin of detected dust in particulate matters, observed in Bulgaria.





# Thank you for your attention!



## **ACKNOWLEDGEMENTS**

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To the NOAA Air Resources Laboratory (ARL) for the provision of the HYSPLIT model and READY website (<http://www.ready.noaa.gov>)

R-project website (<https://www.r-project.org/>) for Package ‘openair’

The Barcelona Dust Forecast Center (<https://dust.aemet.es>).