Exploring Innovative Methods for Air Dust Pollution Monitoring using Satellite Data and Products: A Case Study of Chalkidiki (Greece)

Petra Sedláčková[1], Kostas Gounaris[2], Veronika Kopačková-Strnadová[1]
[1]Czech Geological Survey, [2]Hellas Gold

Funded by
the European Union

Introduction: atmospheric and surface dust monitoring

- Surface mining activities significantly contribute to environmental degradation and pose risk to human health
- One of the main type of pollution is particulate matter that is dispersed into the air through mining processes
- Particulate matter (PM10) or air dust pollutants are particles with an aerodynamic diameter ≤10 µm, suspended in the air
- PM10 particles are inhalable, penetrating into the respiratory tract and can cause respiratory and cardiovascular diseases, long term exposure is linked to reducing lung function
- Monitoring of this type of pollution can be challenging due its spatial distribution in three dimensional space
- Satellite data can offer stable spatial and temporal coverage over large and inaccesible areas

- **Focus on overall dust pollution evaluation and the usability of remote sensing data in the measurement of particular pollution**

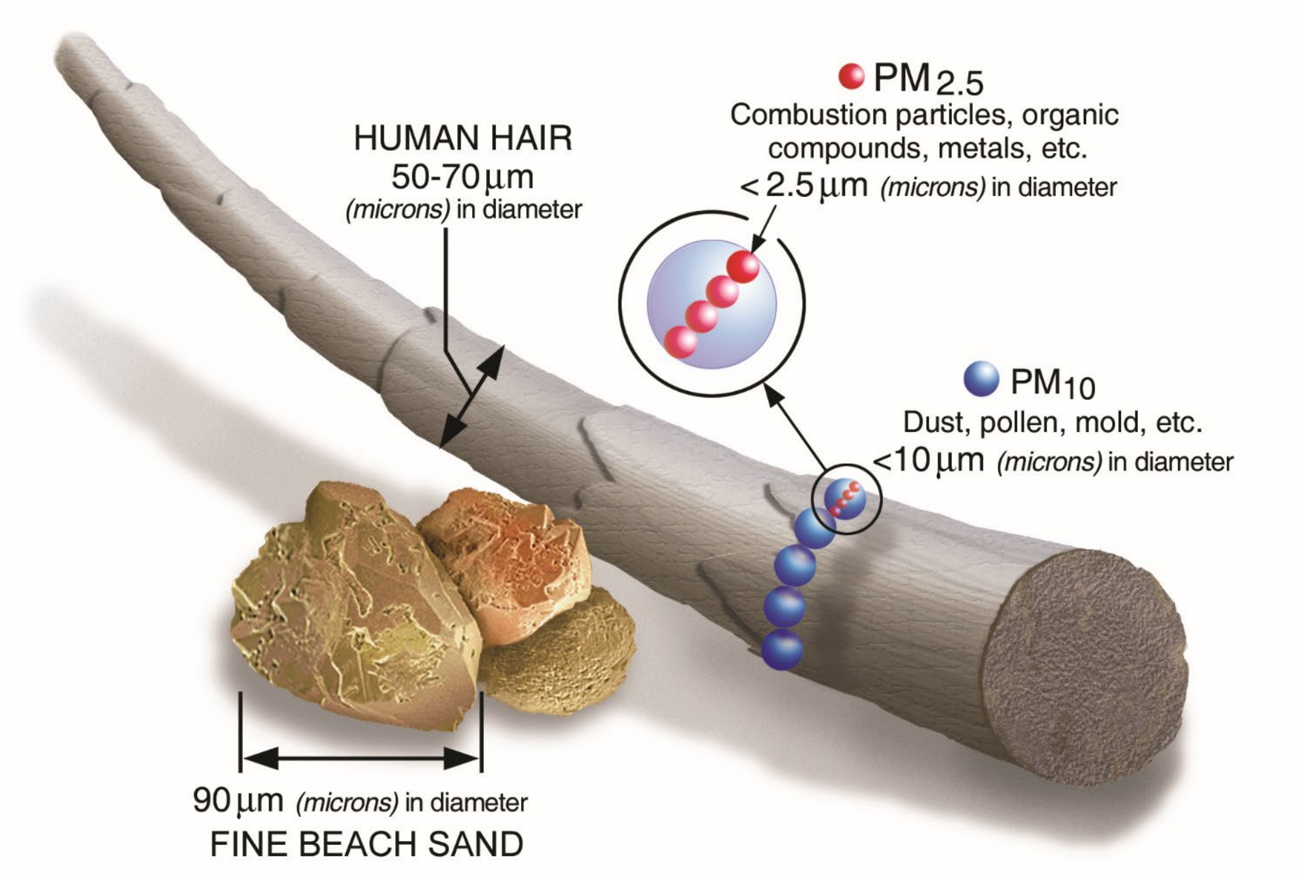


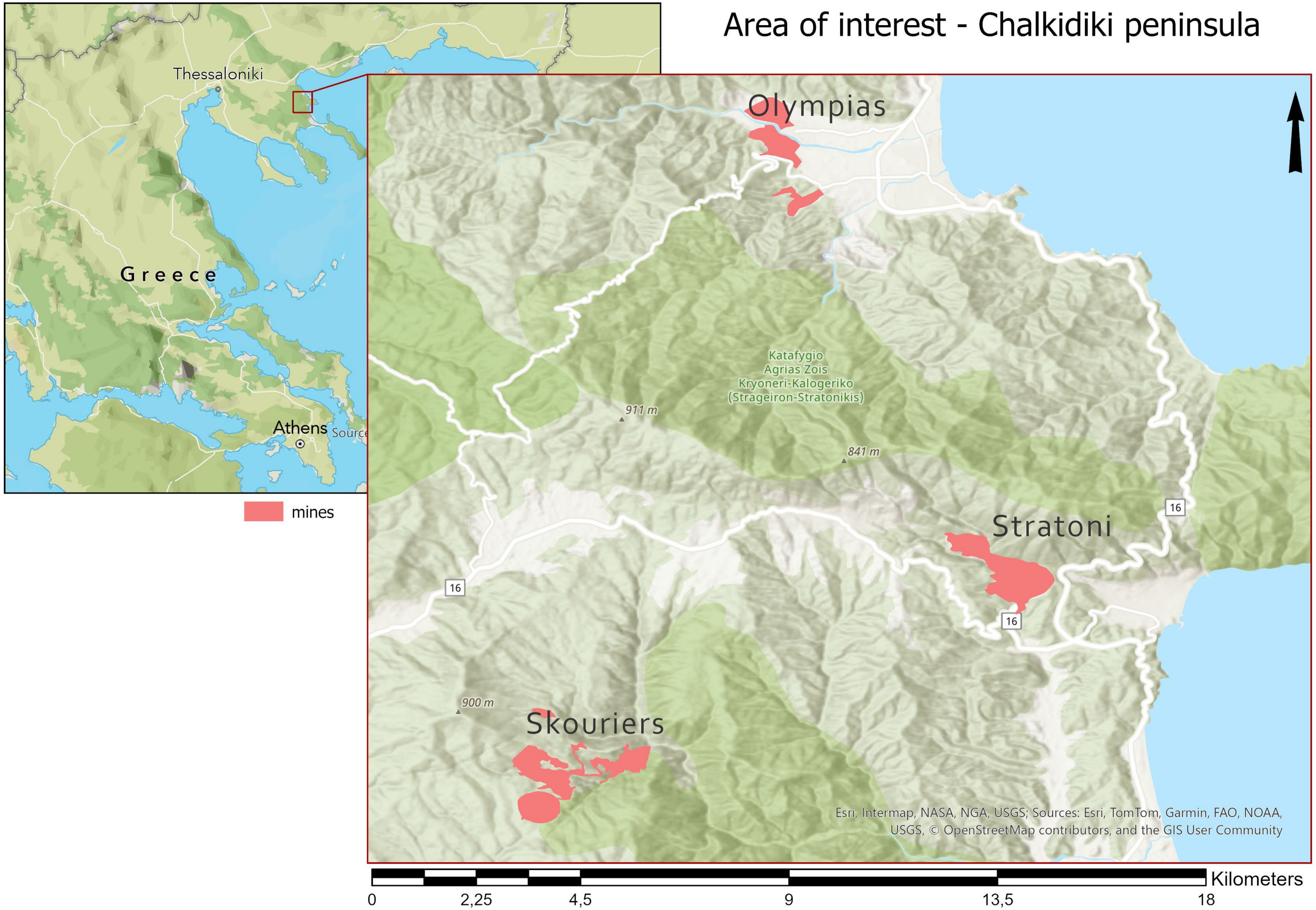
Fig.1 -Environmental Protection Agency, accessed Dec 3, 2024

Funded by the European Union

Test site: Chalkidiki, Greece

- Open pit mining sites operated by Hellas Gold, a subsidiary of Eldorado Gold Corporation
- Copper, gold, silver, lead, zinc

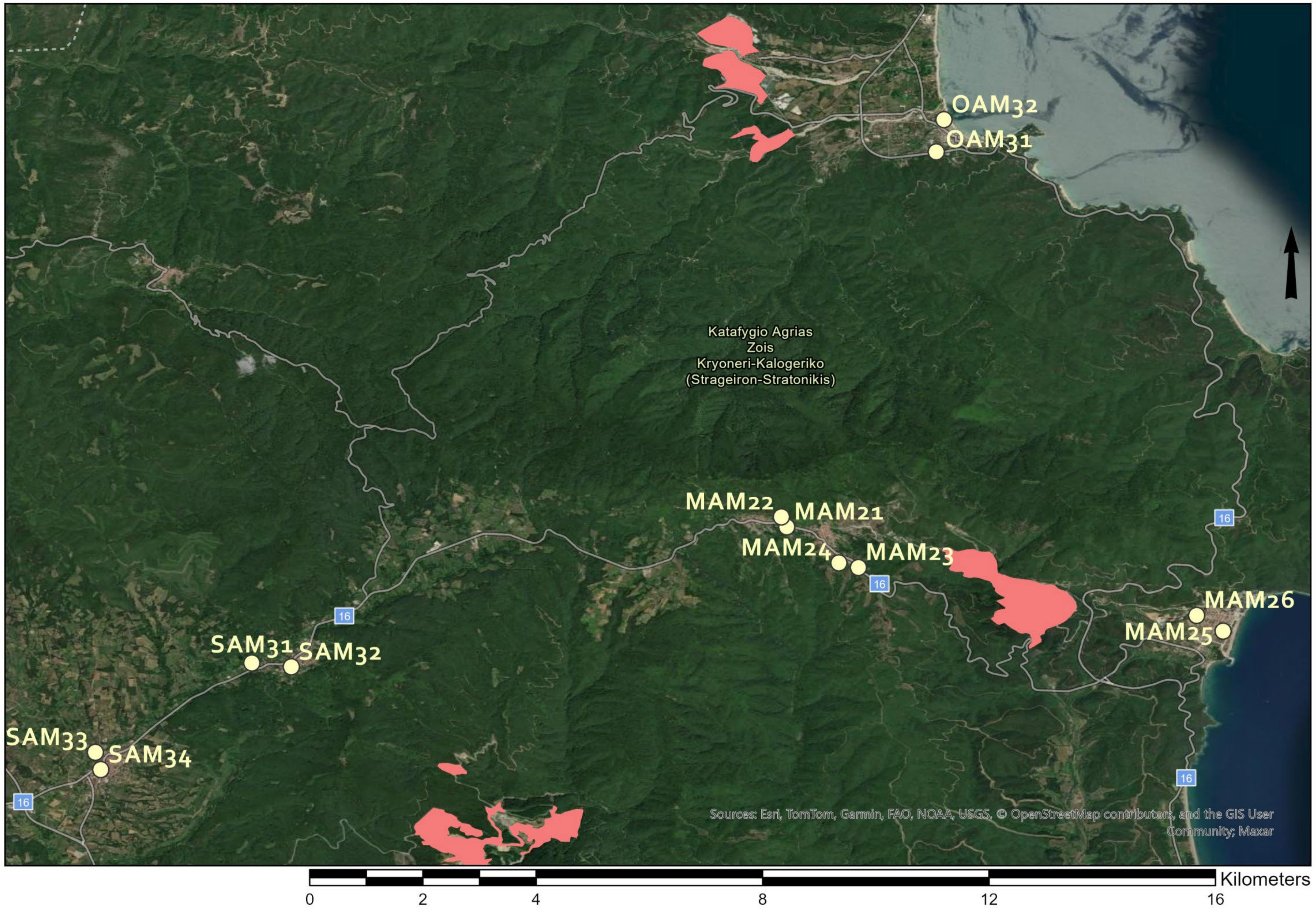
Area of interest - Chalkidiki peninsula



Funded by the European Union

Datasets: IN-SITU measurements of dust in residental areas

- PM10 data from Hellas Gold platform
  - Hourly values of PM10 aggregated in daily medians at 12 stations
  - From 6/2015 to 8/2024 (based on location)
- Data available at https://environmental.hellas-gold.com/

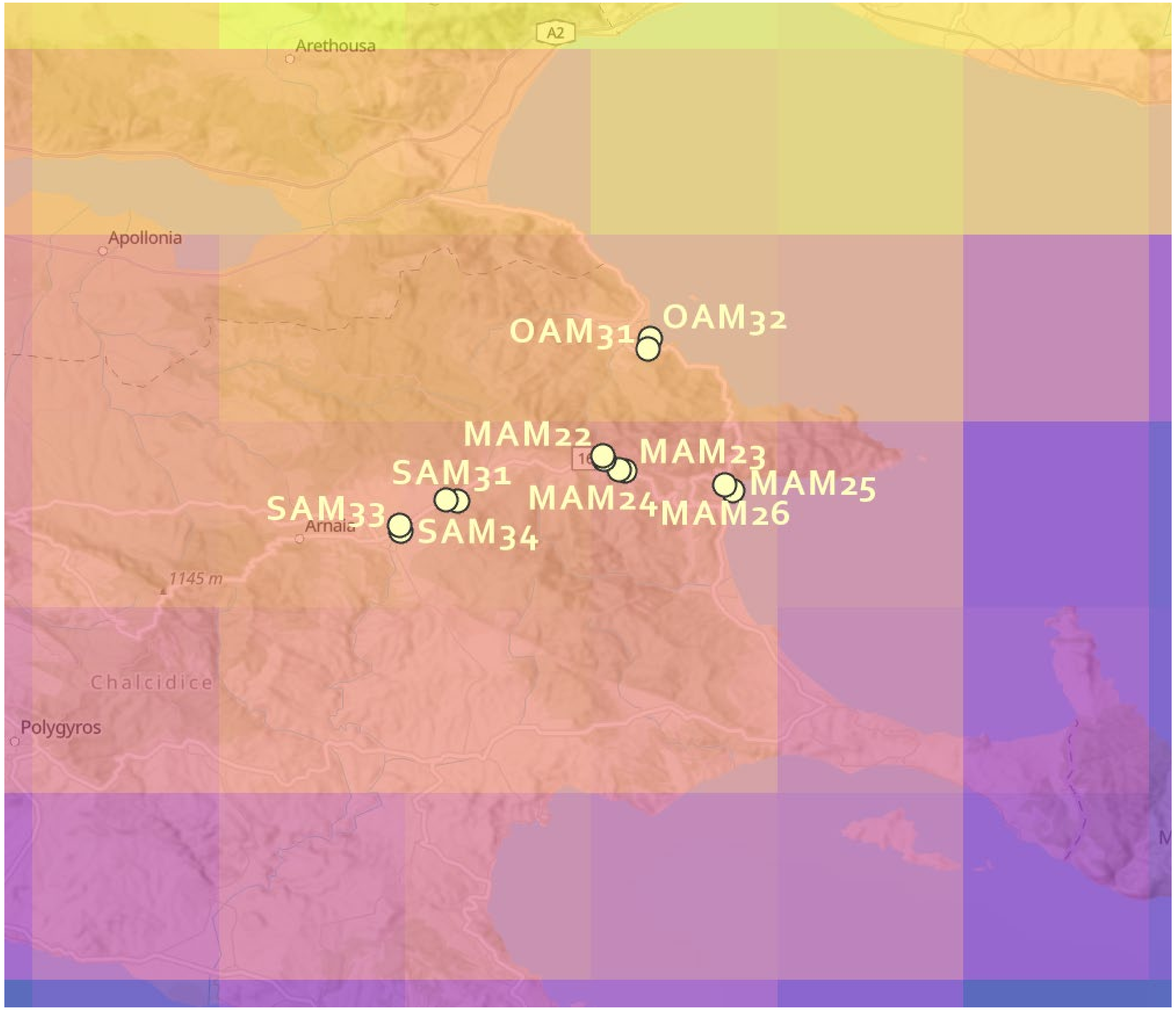


Funded by
the European Union

Datasets: Satelite data product - CAMS

Atmosphere
Monitoring Service
atmosphere.copernicus.eu

- Copernicus Atmosphere Monitoring Service
- Numerical models from satellite and ground based observations
- CAMS European air quality reanalyses and analysis data
  - Particulate matter < 10 µm (PM10)
  - Level 0
  - Hourly values aggregated in daily medians
  - From 1/2015 to 8/2024
  - Spatial resolution ~10 km



Funded by
the European Union

Datasets: Satelite data - MODIS

- NASA's Terra and Aqua satellites
- Remote sensing measurements of aerosol optical depth
- Optical depth of atmosphere
  - MOD04_L2 – Optical_Depth_Land_And_Ocean
    - 10 km
  - MOD04_3K – Optical_Depth_Land_And_Ocean
    - 3 km
  - MAIAC MCD19A2.061 – Optical _Depth_055
    - 1 km
- Data aggregated into daily medians (max. four overpass per day)

MOD04_3K Land and ocean AOD from 29.8. 2024

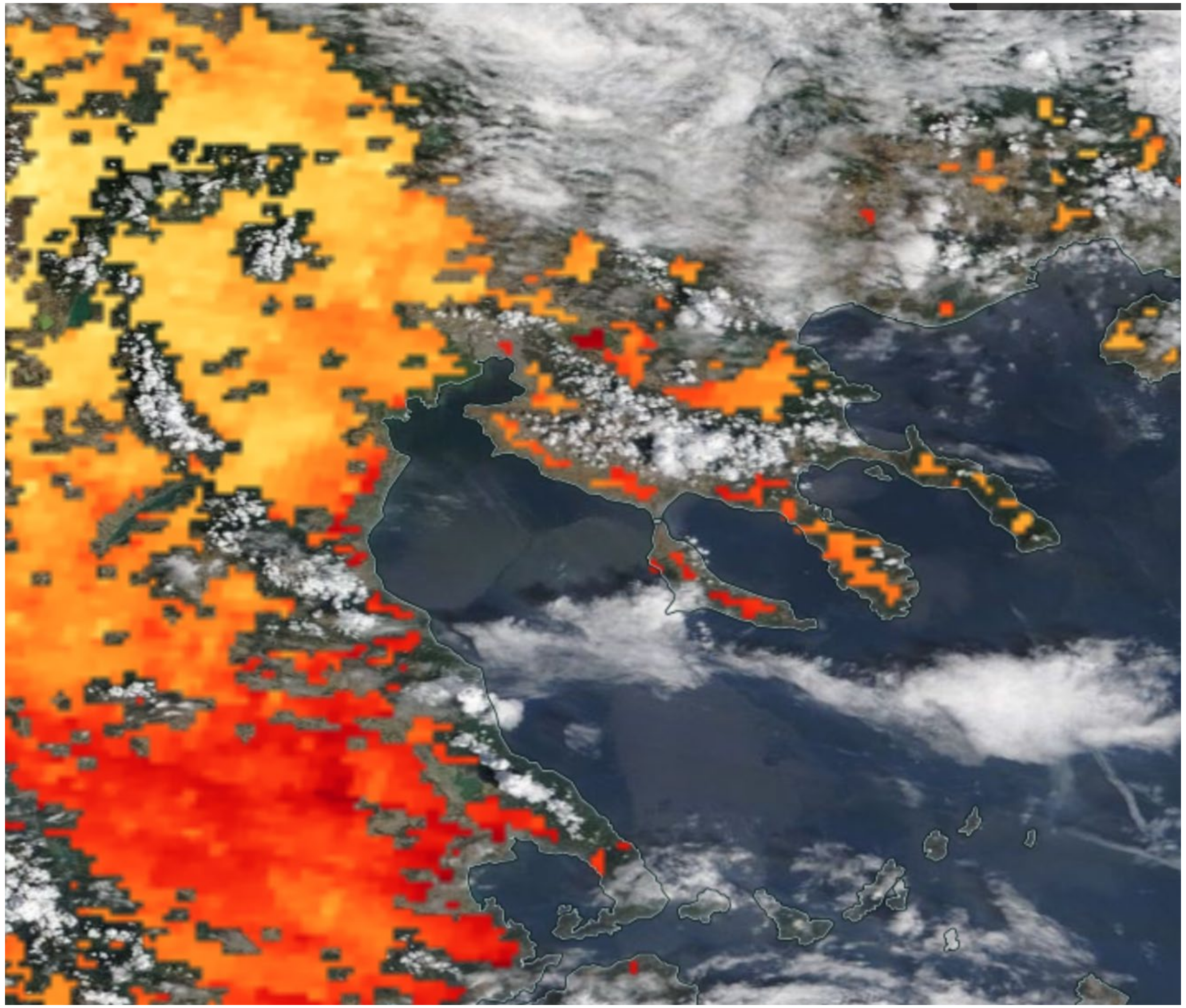


Fig.2 - NASA Worldview Snapshots, accessed Dec 2, 2024

Funded by
the European Union

Methodology

Preprocessing	Data Acquisition: data downloaded via API python scripts for 1/2015 - 8/2024 related to station positions and aggregated in to daily median values Spatial data aggregation: based on CAMS resolution – means from „pixel containing“ stations measurements
Correlation Analysis	Spearman correlation for observing relationships in: • Three AOD MODIS datasets and IN-SITU data for year 2015 • CAMS, MODIS and IN-SITU datasets for individual station measurements and satellite-derived values for 2015 - 2024
Station Specificity Analysis	PCA analysis of in-situ time series data for observing similarity in stations measurements and time series visualization – annual and monthly means
Trends and Seasonality Analysis	Seasonal decomposition of time series into trend, seasonal and residual variables, observing differencies between CAMS and IN-SITU datasets
Prophet Forecasting	Used Meta prophet forecasting procedure for modelling and predicting seasonal trends for both CAMS and IN-SITU clustered data Useful for predicting time series with strong seasonality on longer time series • Trained on 2015-2023 monthly values • Validation with 2024 data • Prediction extended to the end of 2025
Spatial Trends and Seasonality	PCA analysis of CAMS rasters divided in wet season (Nov-Apr) and dry season (May-Oct) for main wind directions and dust hotspots observing

Funded by
the European Union

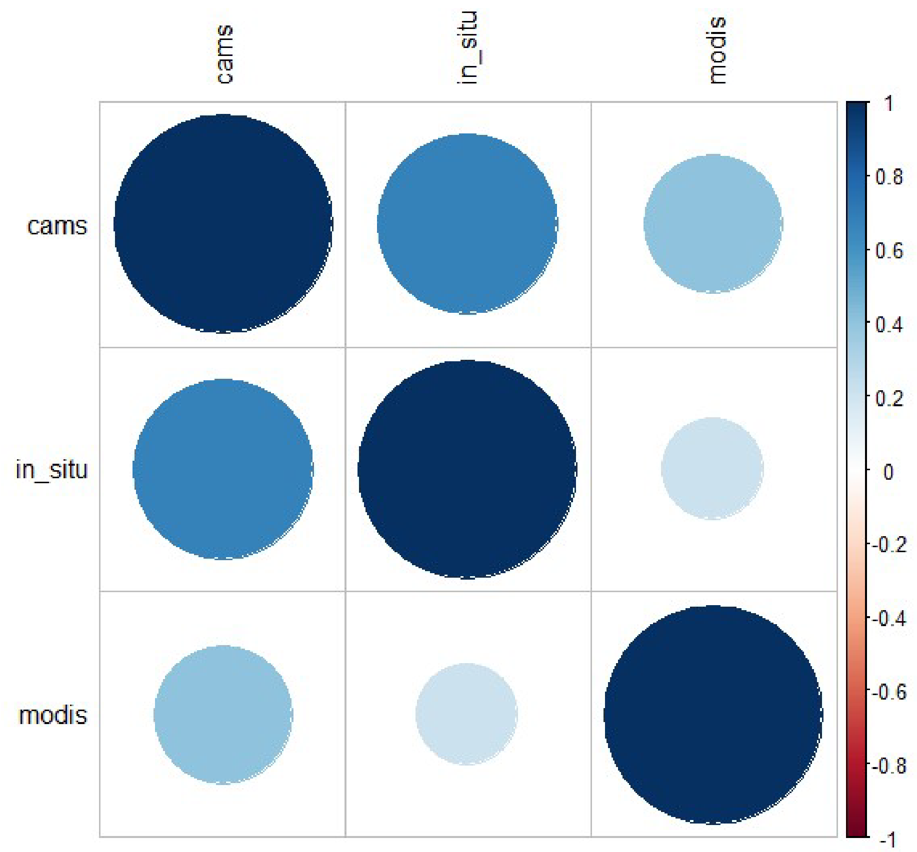
Results: Correlations

Correlations of **MODIS** datasets

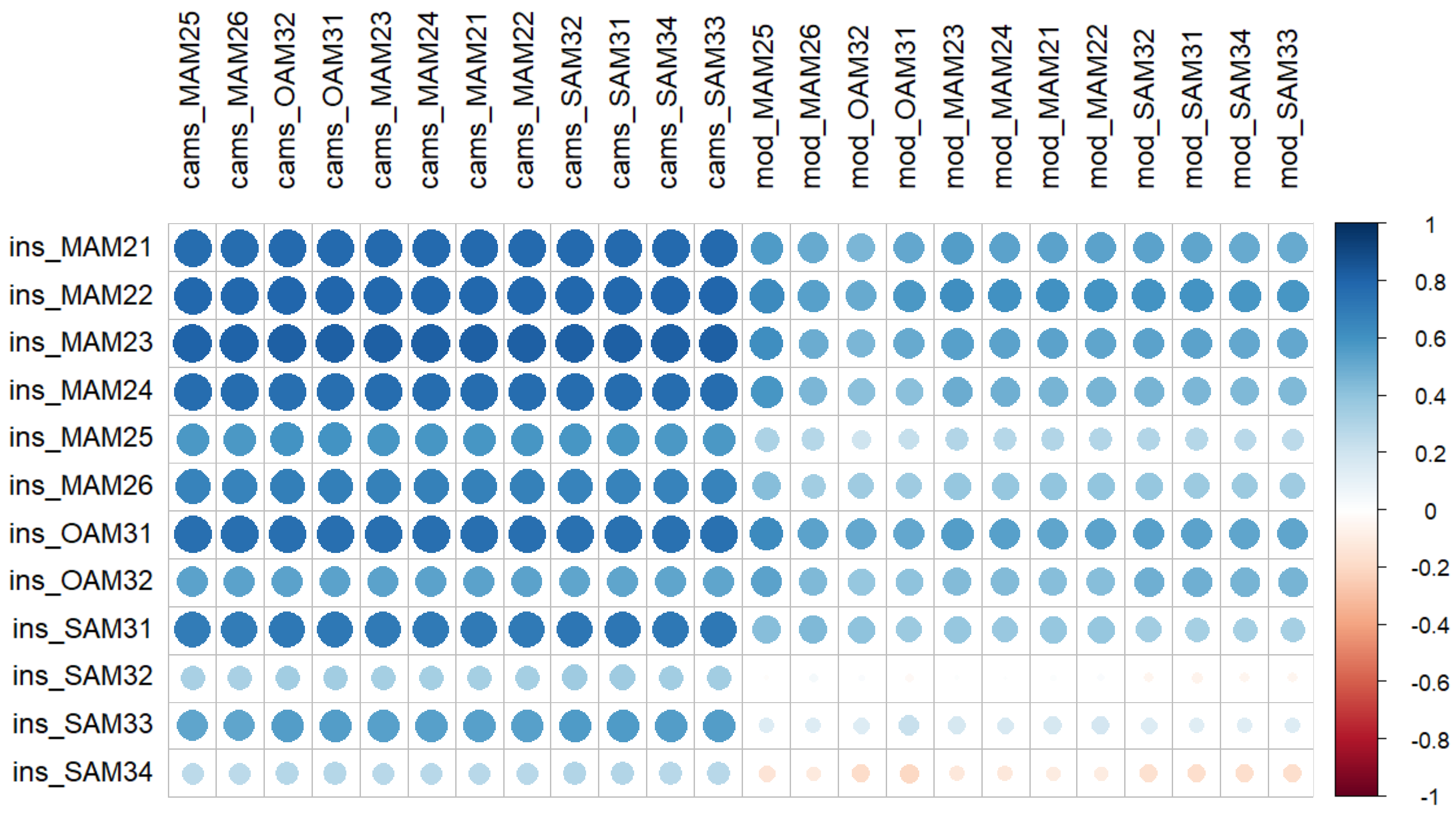
- Examination of three AOD datasets – MOD04_L2, MOD04_3K, MCD19a2.061
- Challenging due cloud coverage and missing values
- MOD04_3k best results based on highest available measurements and highest correlation with in-situ
- **rs ≈ 0,35 (based on location), 61,9% missing values -> insufficient, will not be used**

CAMS correlations

- Examination of pm10 variable
- Challenging due low spatial resolution, lack of identifying local extremes
- **rs ≈ 0,72 (based on location) -> sufficient, will be examined deeper**



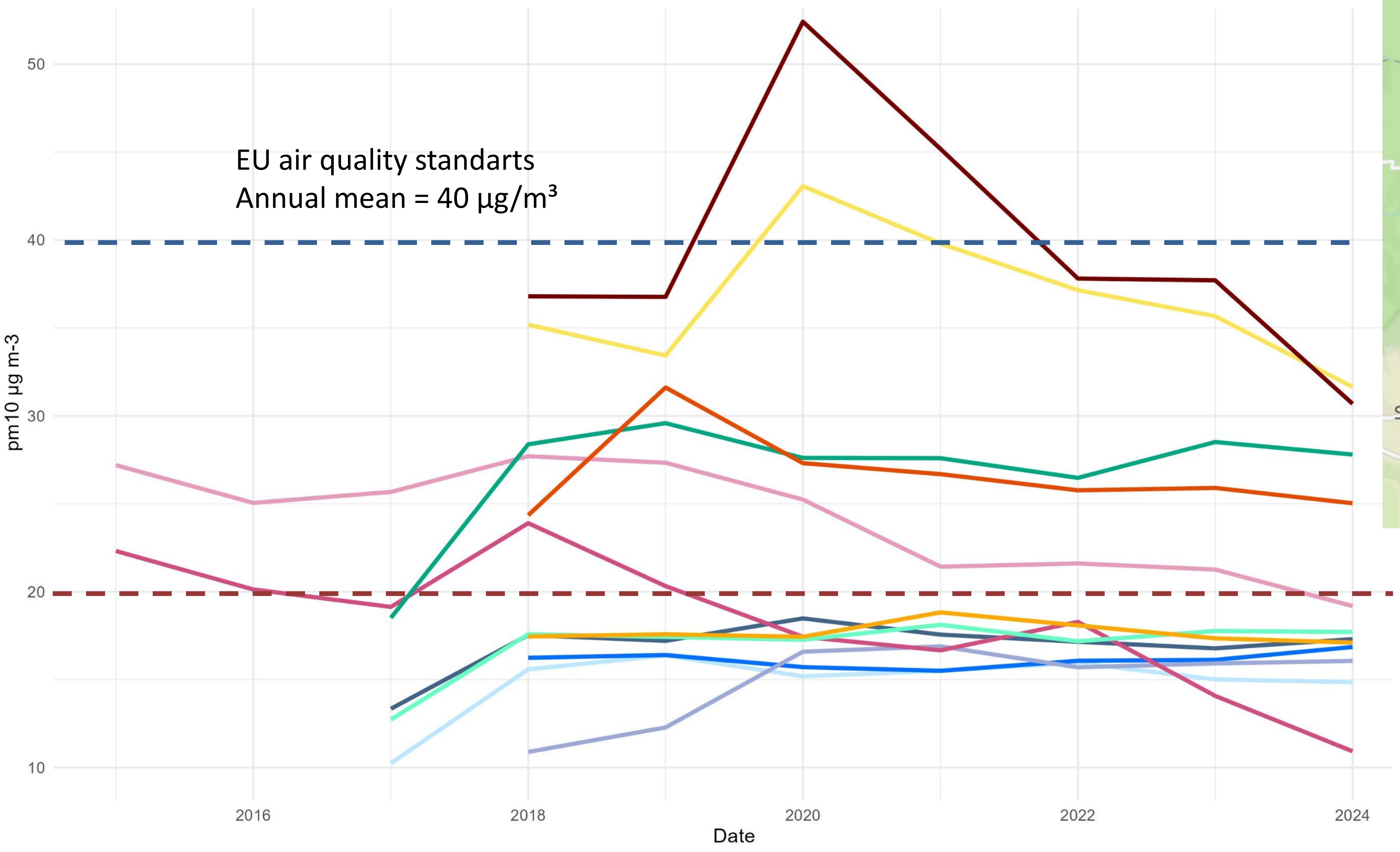
Correlation between datasets

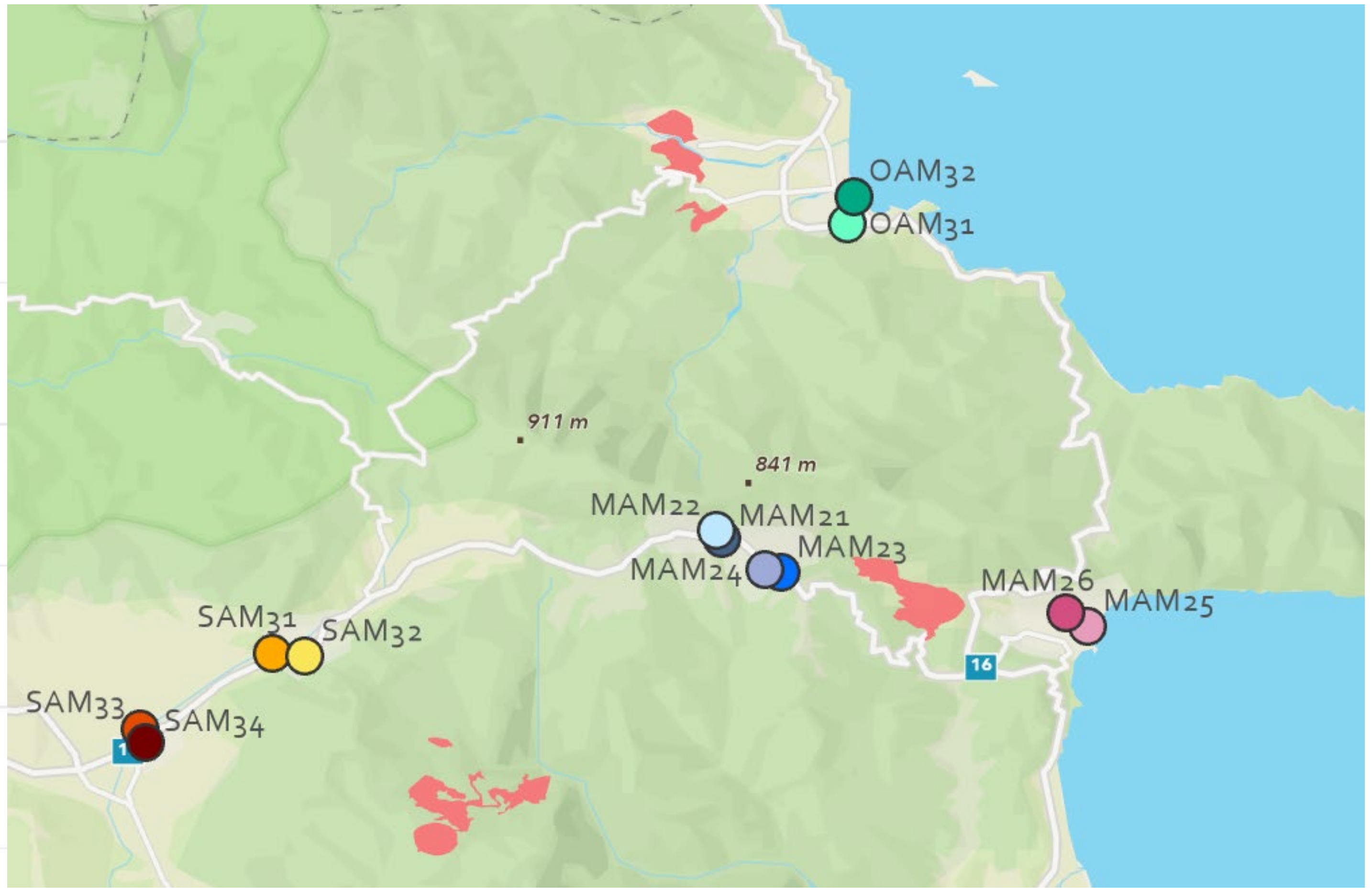


Correlation between sites datasets measurements

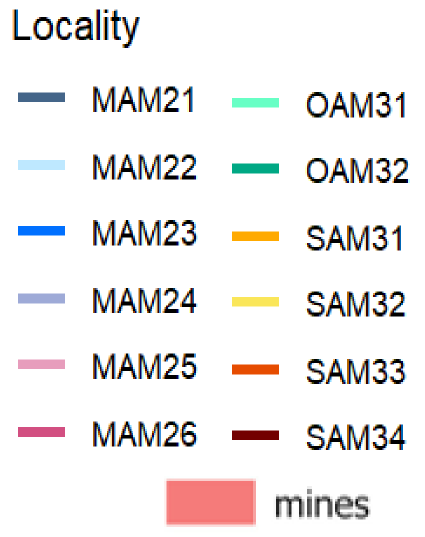
Funded by the European Union

Analysis of stations: annual IN-SITU means



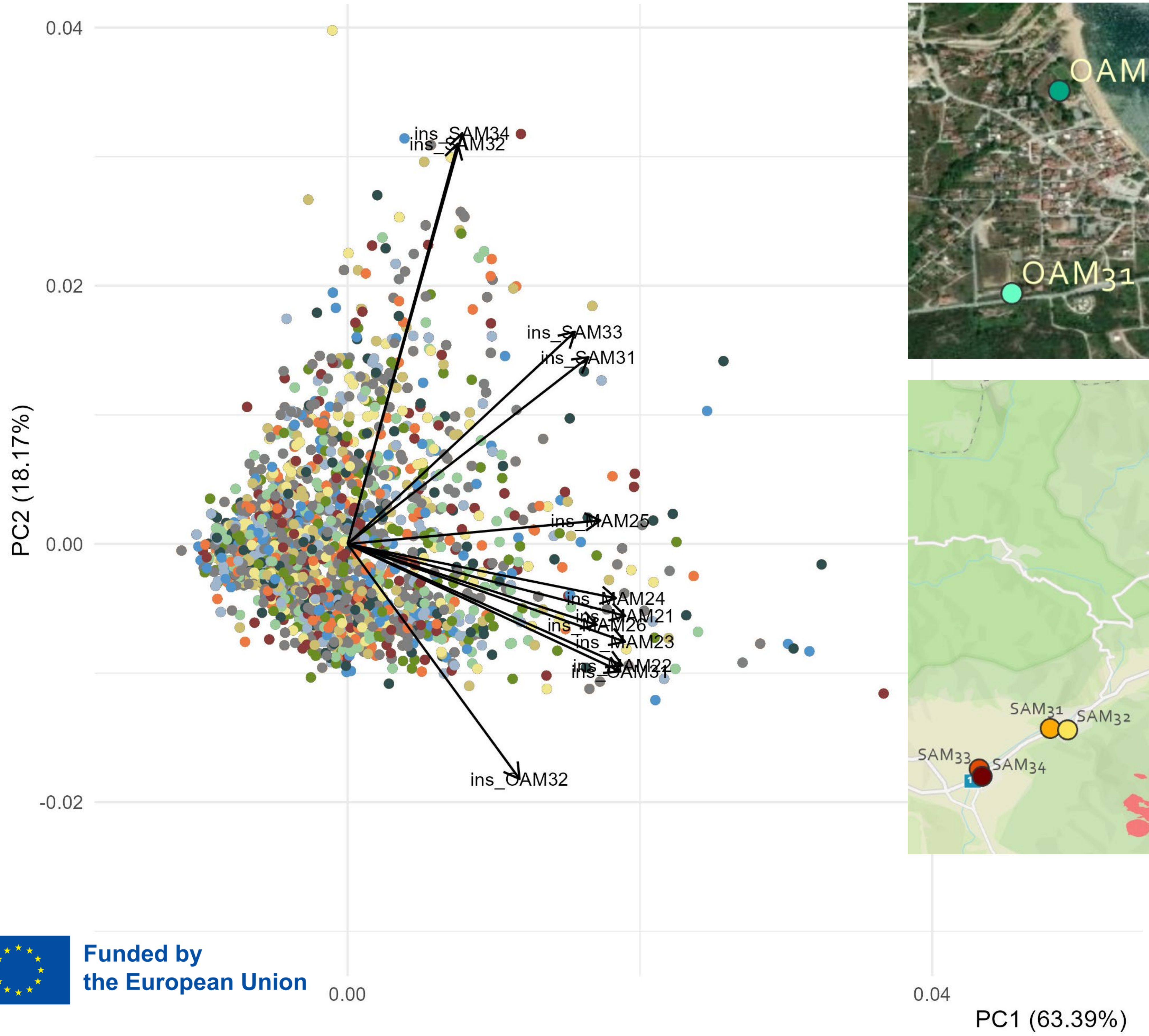


WHO annual mean guideline
Annual mean = 20 µg/m³



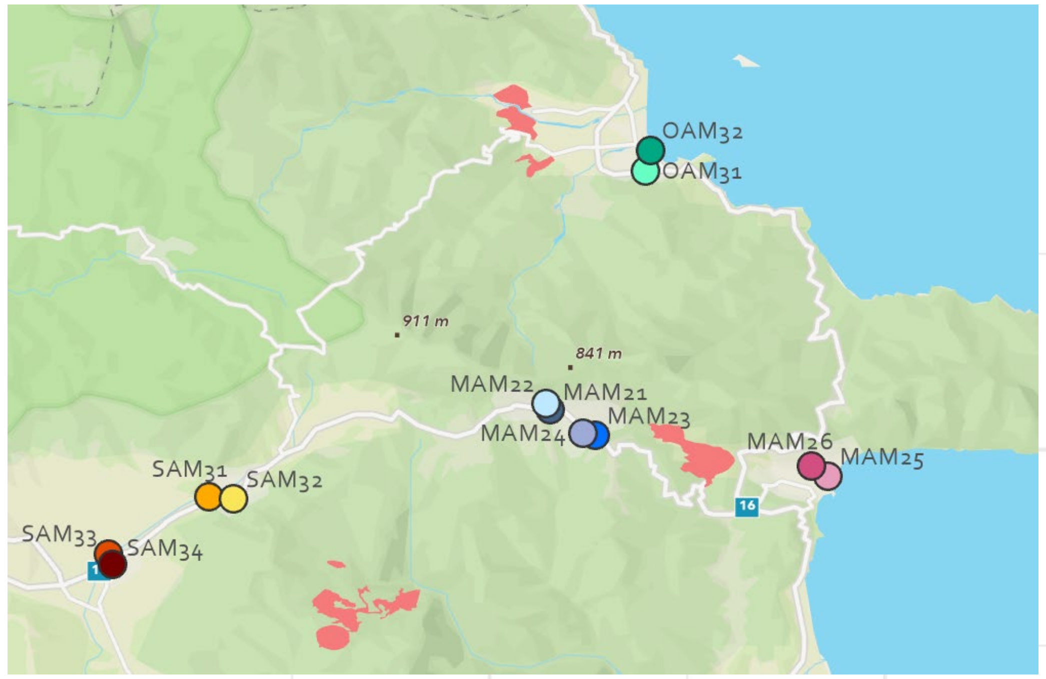
Funded by
the European Union

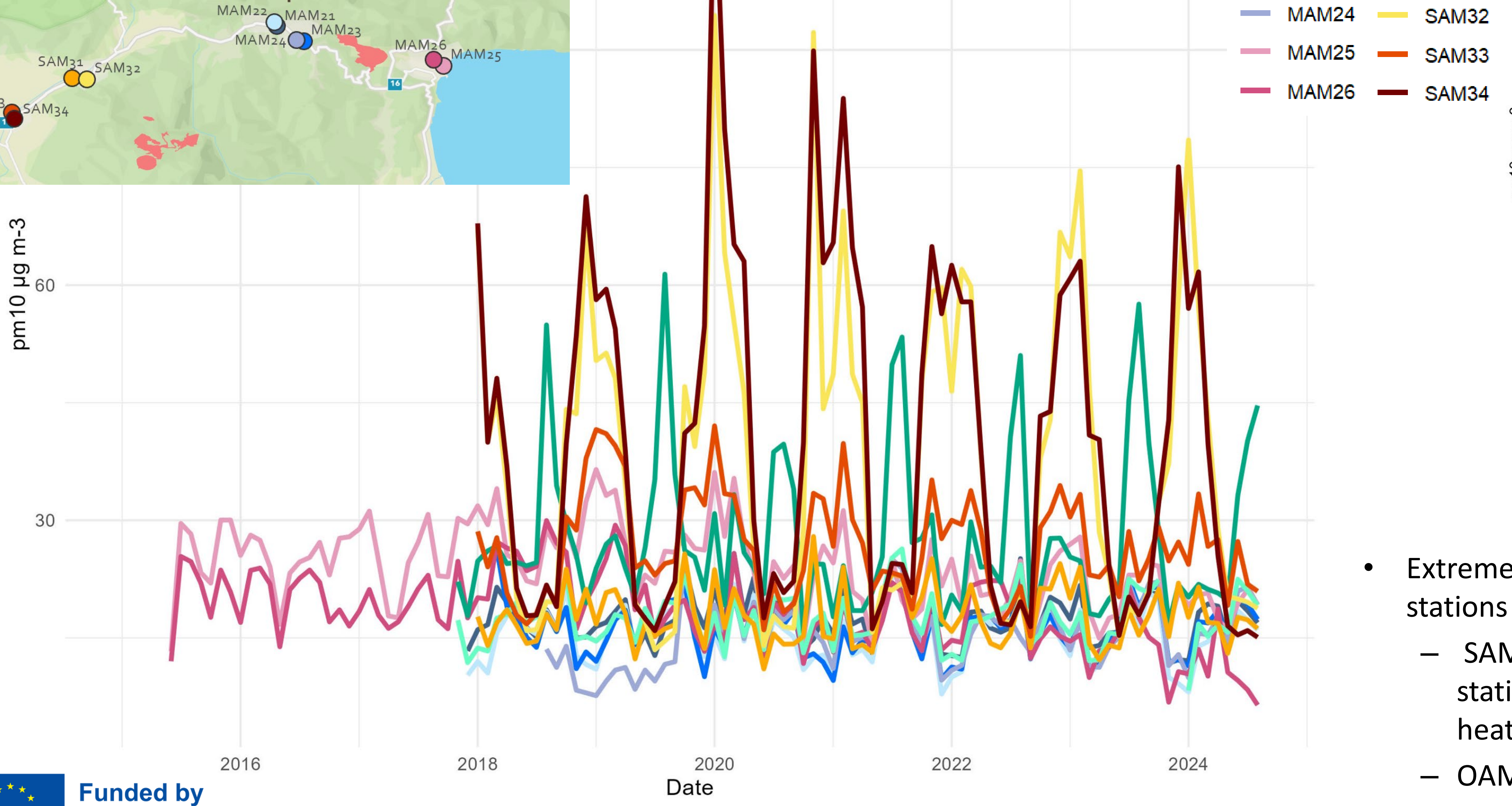
Station-Specific Insights: PCA analysis of stations

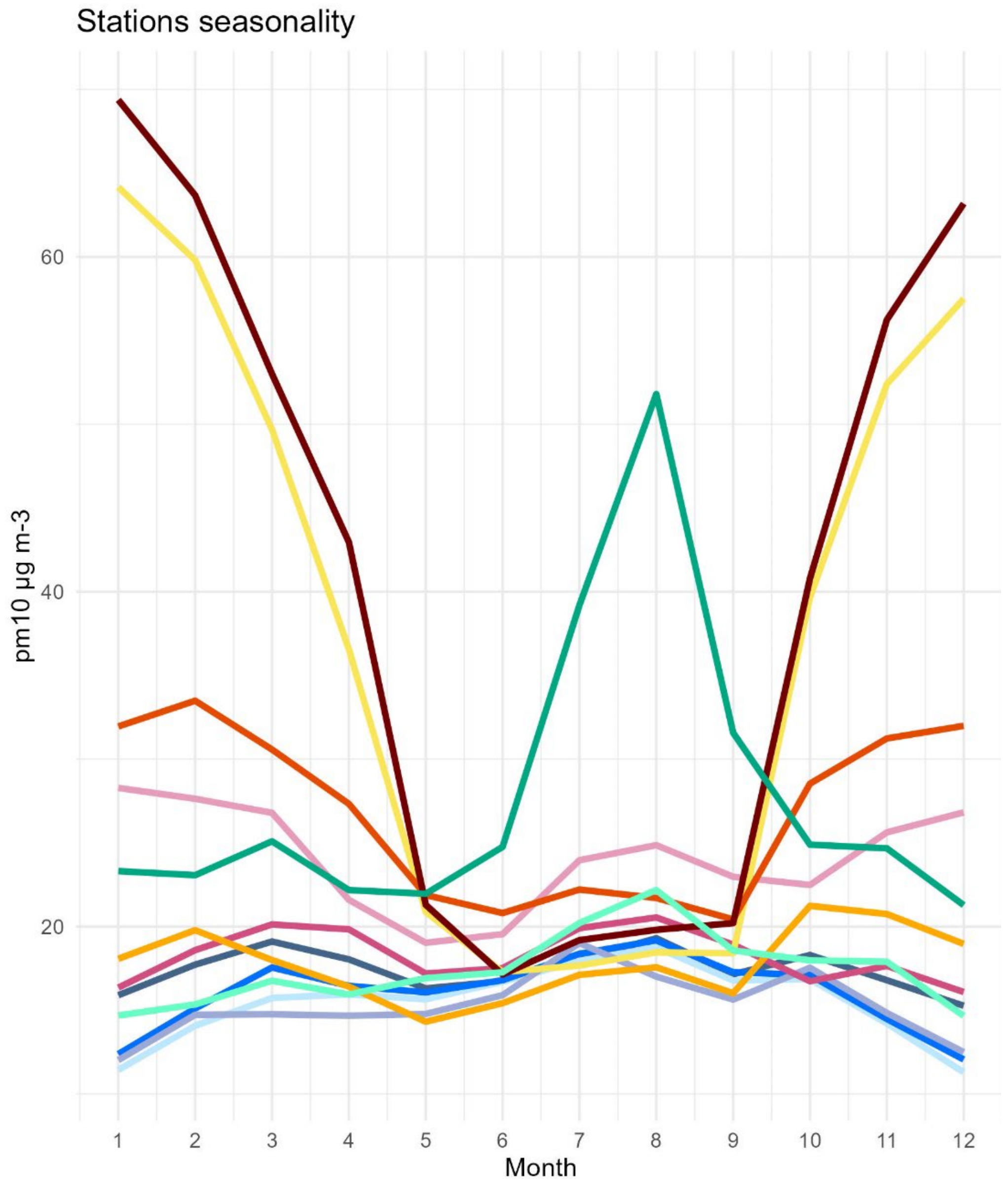


Funded by
the European Union

Station-Specific Insights: IN-SITU monthly means





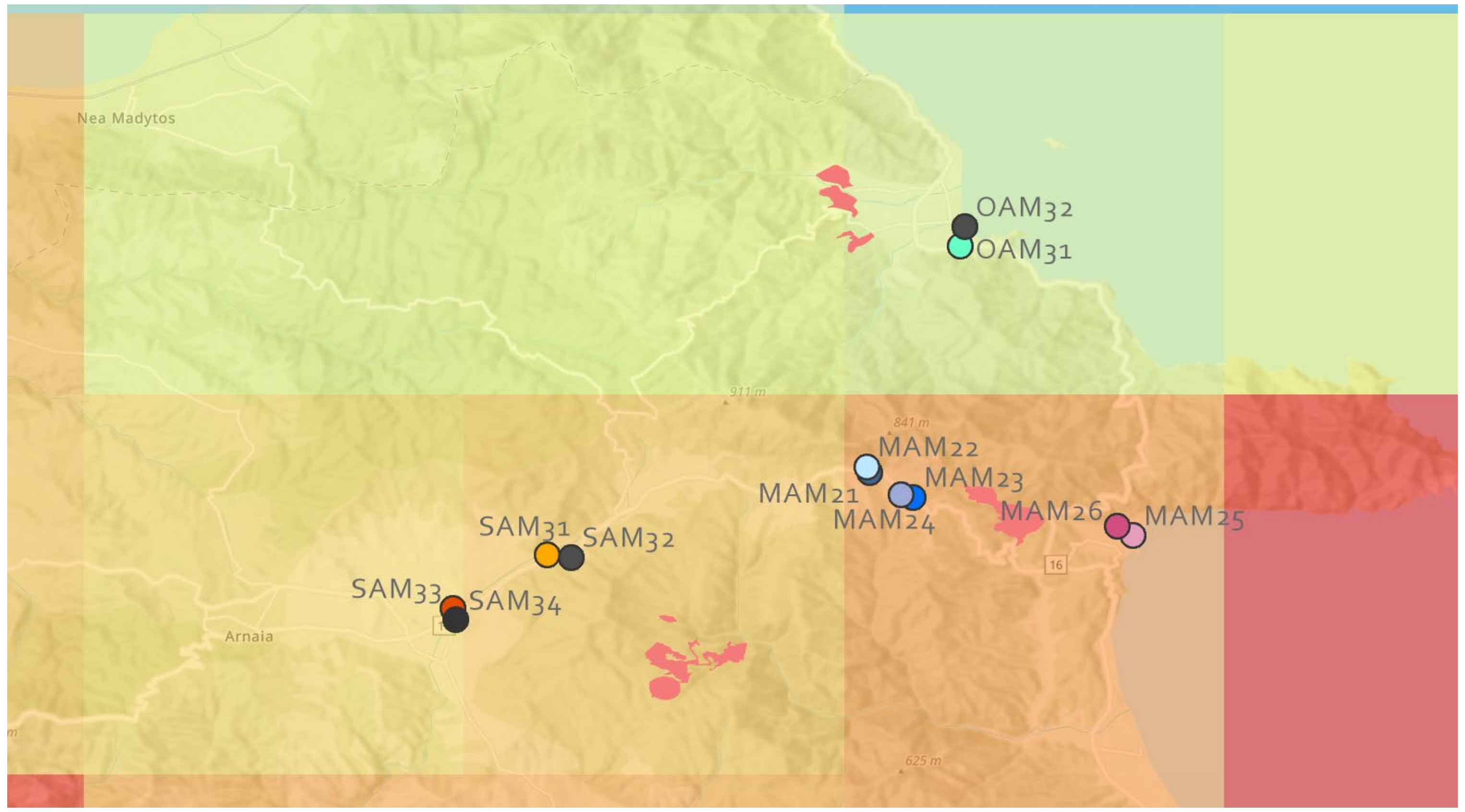


- Extremely height values repeatedly observed at three stations
  - SAM34, SAM32 – winter time extremes due to the stations locations situated in residental area where heating activity results in higher emissions
  - OAM32 – summer time extremes due to the sandy seaside possition

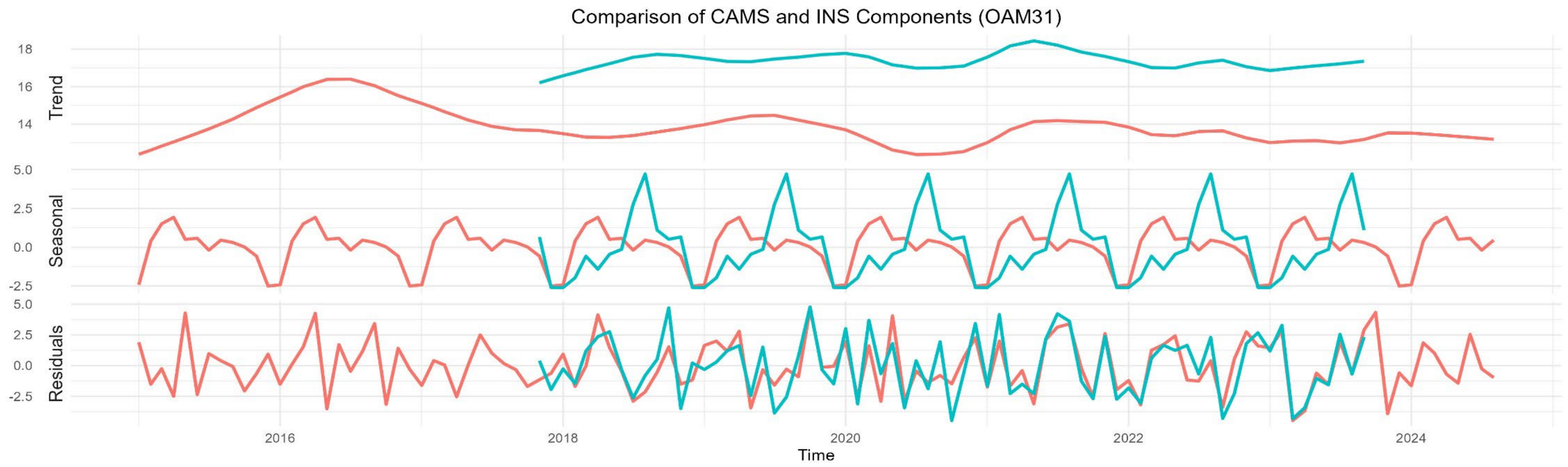
Funded by
the European Union

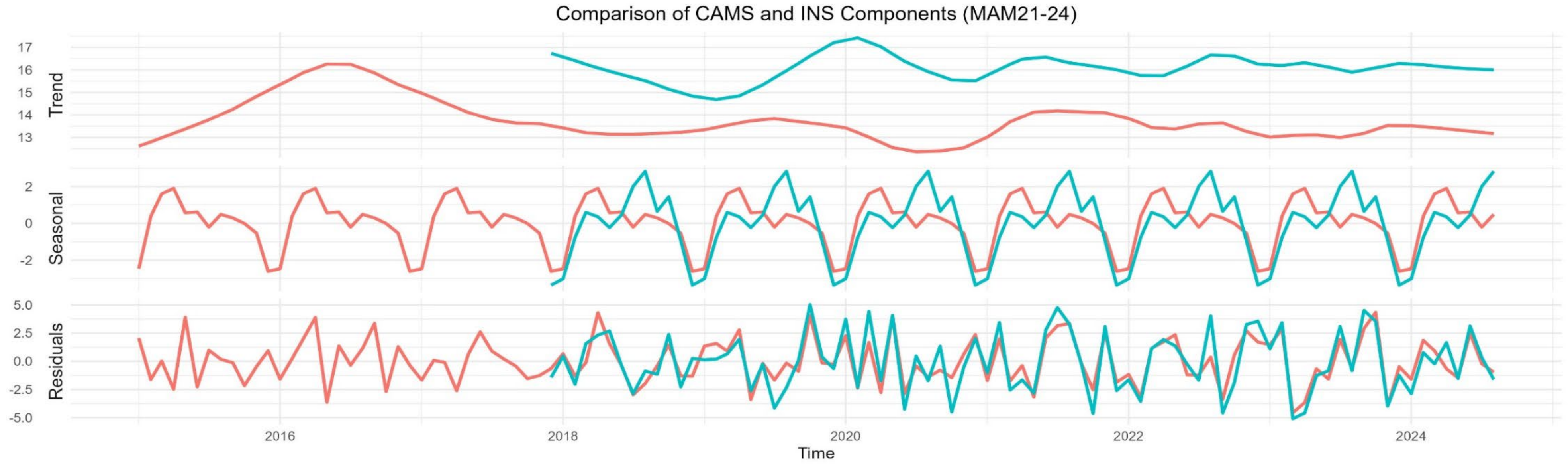
Seasonality – Trends: decompositions

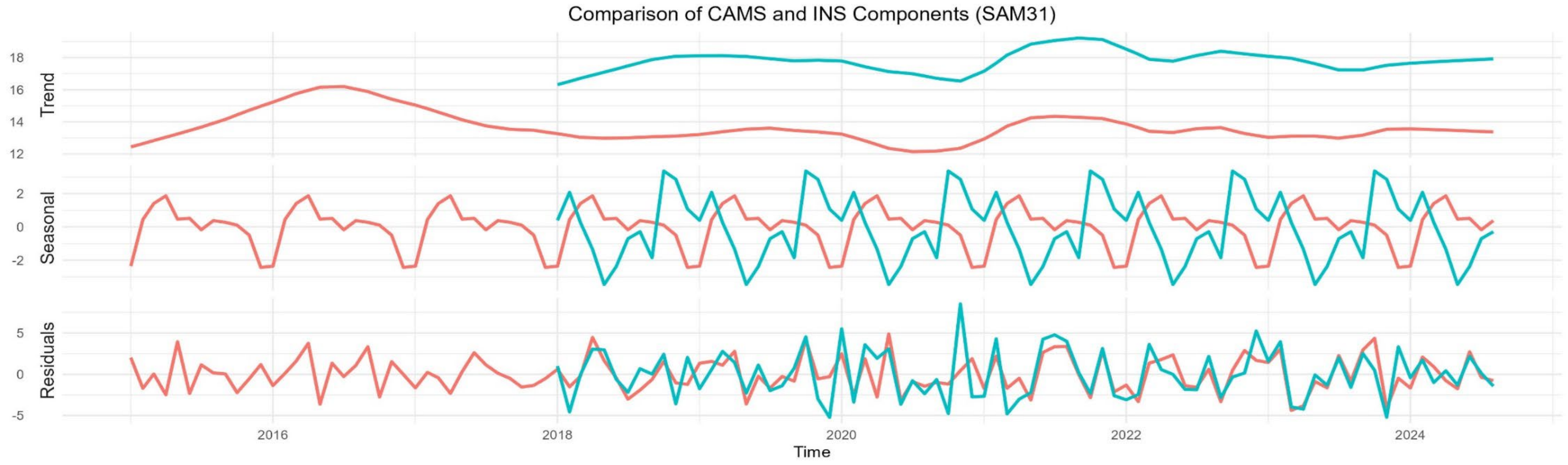
- Seasonal decomposition of monthly CAMS and clustered IN-SITU data



- The correlation between both datasets can be observed in the trend component, with in situ always reaching higher values by 5 – 15 µg/m³



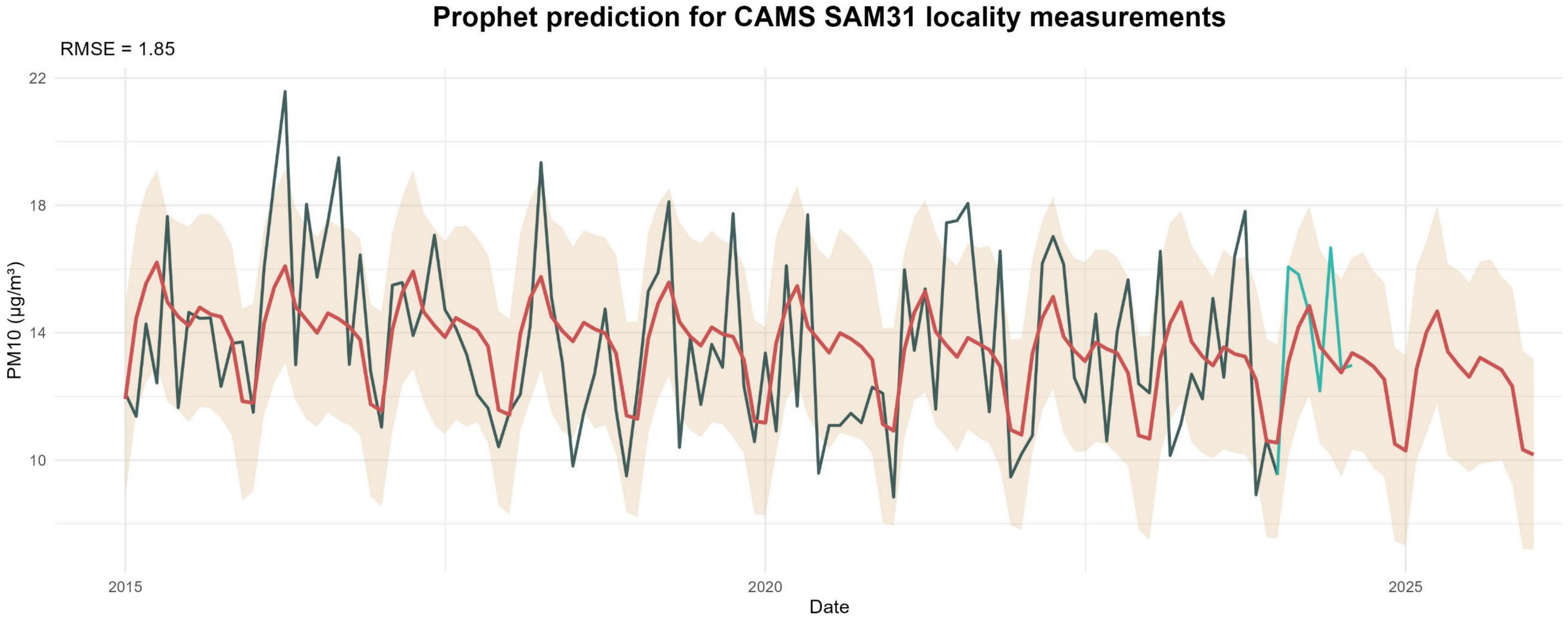


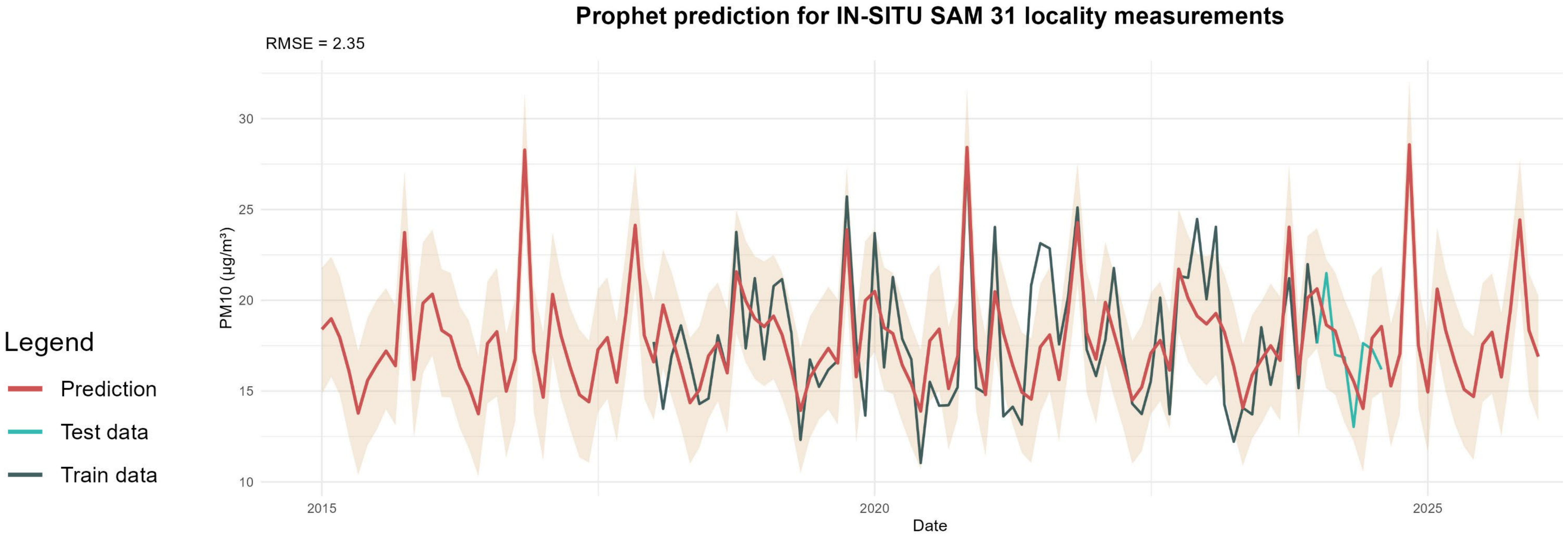


Funded by the European Union

Seasonality – Trends: predictions

- Predictions of balanced, sligtly decreasing trend
- Better results on CAMS dataset
  - r ≈ 0,7 with RMSE ≈ 1,7 μg/m³
- IN-SITU results
  - r ≈ 0,35 with RMSE ≈ 3,5 μg/m³

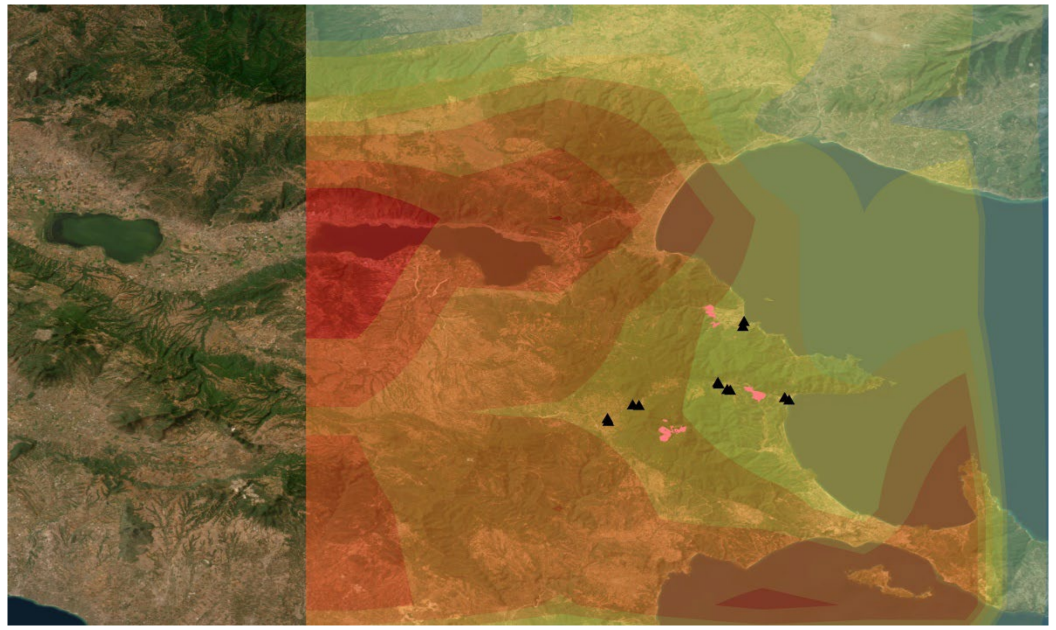




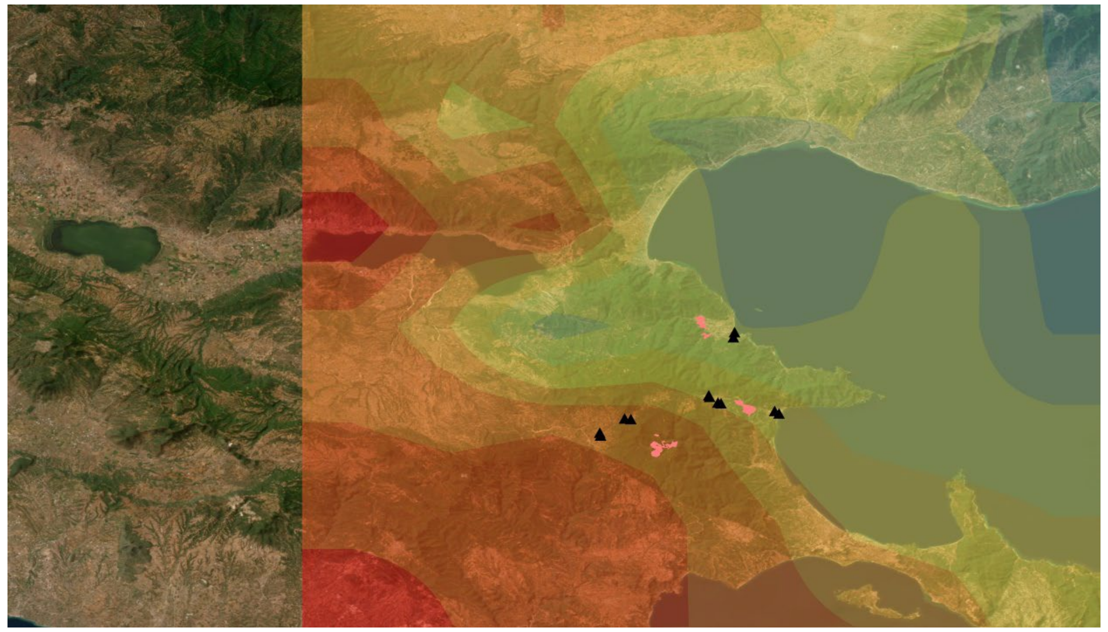
Funded by the European Union

Results: Spatial trends and seasonality

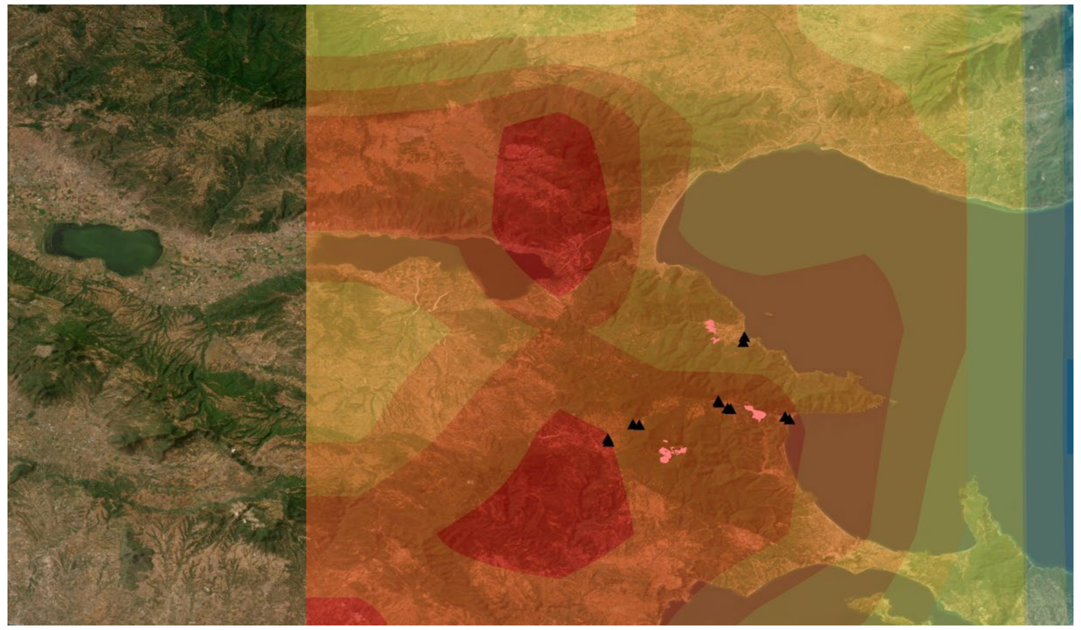
winter season (Nov-April)



2022-2023, 2019-2020

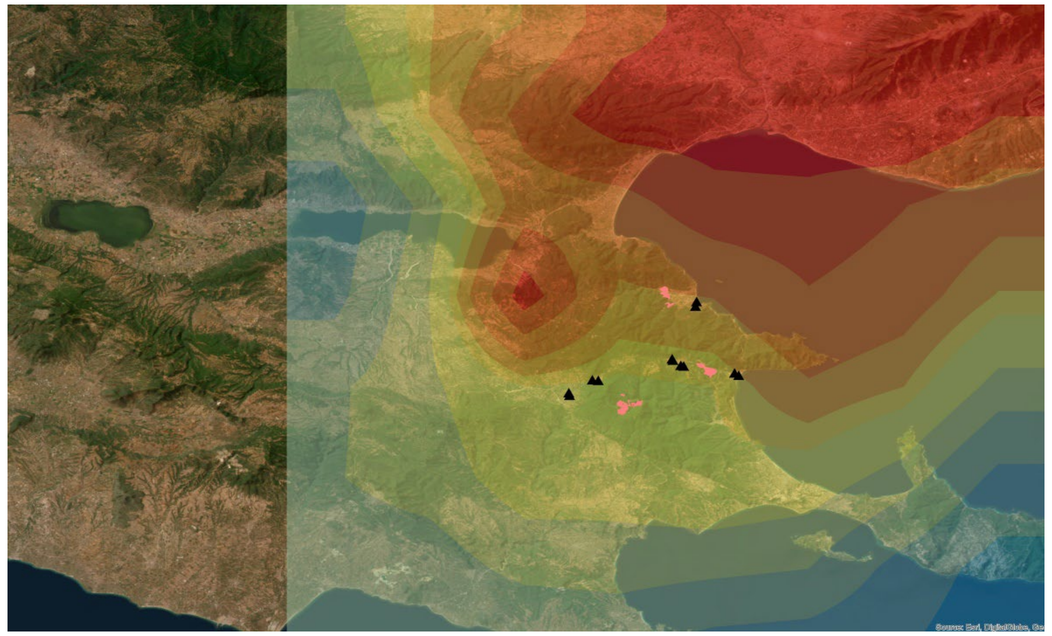


2021-2022, 2020-2021, 2018-2019, 2017-2018

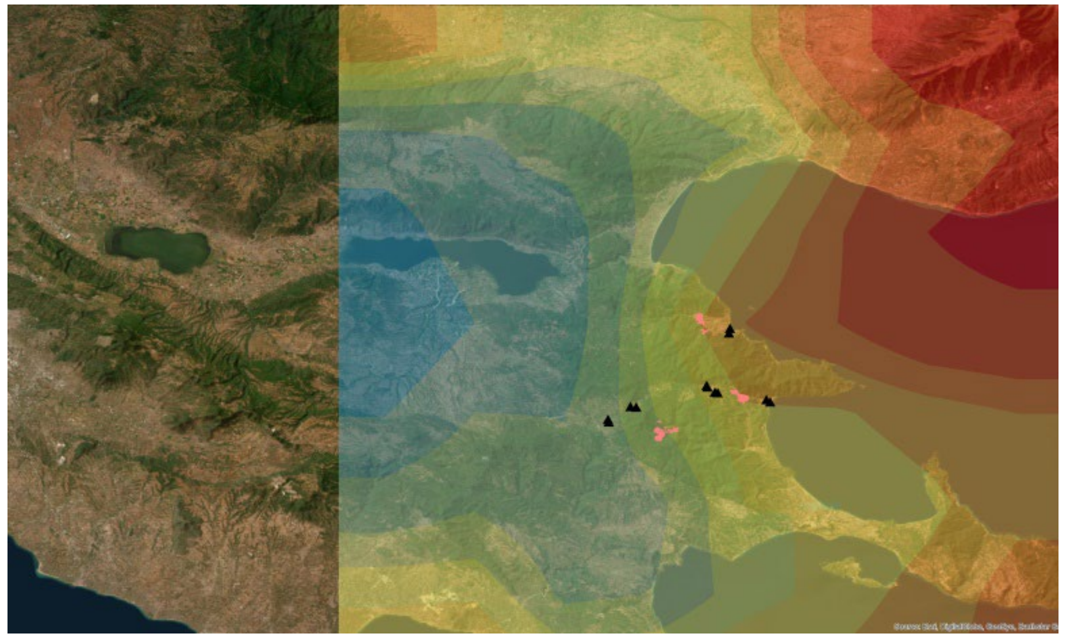


2020-2021, 2015-2016

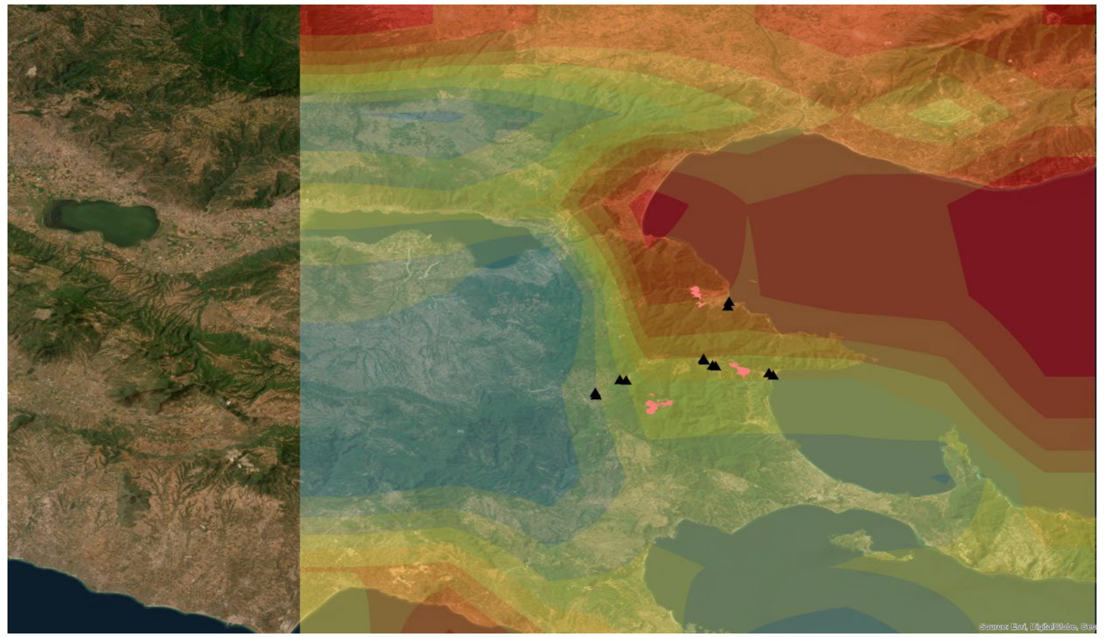
summer season (May-Oct)



2022-2023, 2016-2017



2021-2022, 2015-2016



2020-2021, 2018-2019, 2017-2018

Funded by
the European Union

Conclusion – future remarks

Conclusion

- A strong correlation was found between the CAMS dataset and in-situ measurements ($r_s \approx 0{,}72$), surpassing the correlation seen when using MODIS data ($r_s \approx 0{,}35$)
- Seasonal patterns and trends effectively identified using IN-SITU time series decomposition for years 2015-2024
- Prophet forecasting demonstrated reliable predictions of seasonal trends and confirmed decreasing trend in local pollution
- PCA revealed distinct station characteristics depending on surrounding environments
- PCA facilitated the visualization of distinct seasonal spatial patterns (winter/summer) in dust distribution

Future remarks

- Focusing on use of more advanced machine learning forecasting models
- Exploring new remote sensing data e.g. Dust RGB SEVIRI product
- Aplication of this workflow at second locality in Ihalainen, Finland

Funded by the European Union

MultiMiner
Earth Observation for Smart Mining

ČESKÁ GEOLOGICKÁ SLUŽBA 1919

Thank you.

petra.sedlackova@geology.cz

@MultiMiner_ EU

MultiMiner

multiminer.eu

Funded by
the European Union

Sources

- Fig.1- Environmental Protection Agency (EPA). (n.d.). *Size comparisons for PM particles*. Retrieved December 3, 2024, from https://www.epa.gov/pm-pollution/particulate-matter-pm-basics.
- Fig.2- NASA Earth Observing System Data and Information System (EOSDIS). (2024). *NASA Worldview Snapshots*. Retrieved on December 2, 2024, from https://worldview.earthdata.nasa.gov/?v=19.90832584072654,38.52225039100108,26.010412438077346,41.73236976090209&l=Reference_Labels_15m(hidden),Reference_Features_15m(hidden),Coastlines_15m,MODIS_Terra_Aerosol_Optical_Depth_3km,VIIRS_NOAA21_CorrectedReflectance_TrueColor(hidden),VIIRS_NOAA20_CorrectedReflectance_TrueColor(hidden),VIIRS_SNPP_CorrectedReflectance_TrueColor(hidden),MODIS_Aqua_CorrectedReflectance_TrueColor(hidden),MODIS_Terra_CorrectedReflectance_TrueColor&lg=true&t=2024-08-29-T07%3A39%3A52Z

- ACKNOWLEDGEMENTS:
- The presented analysis was conducted under the support of the EC grant MultiMiner. The MultiMiner project is funded by the European Union's Horizon Europe research and innovation actions programme under Grant Agreement No. 10109137474.

Funded by
the European Union