Monitoring of size distribution of ultrafine particles in Tuscany Region

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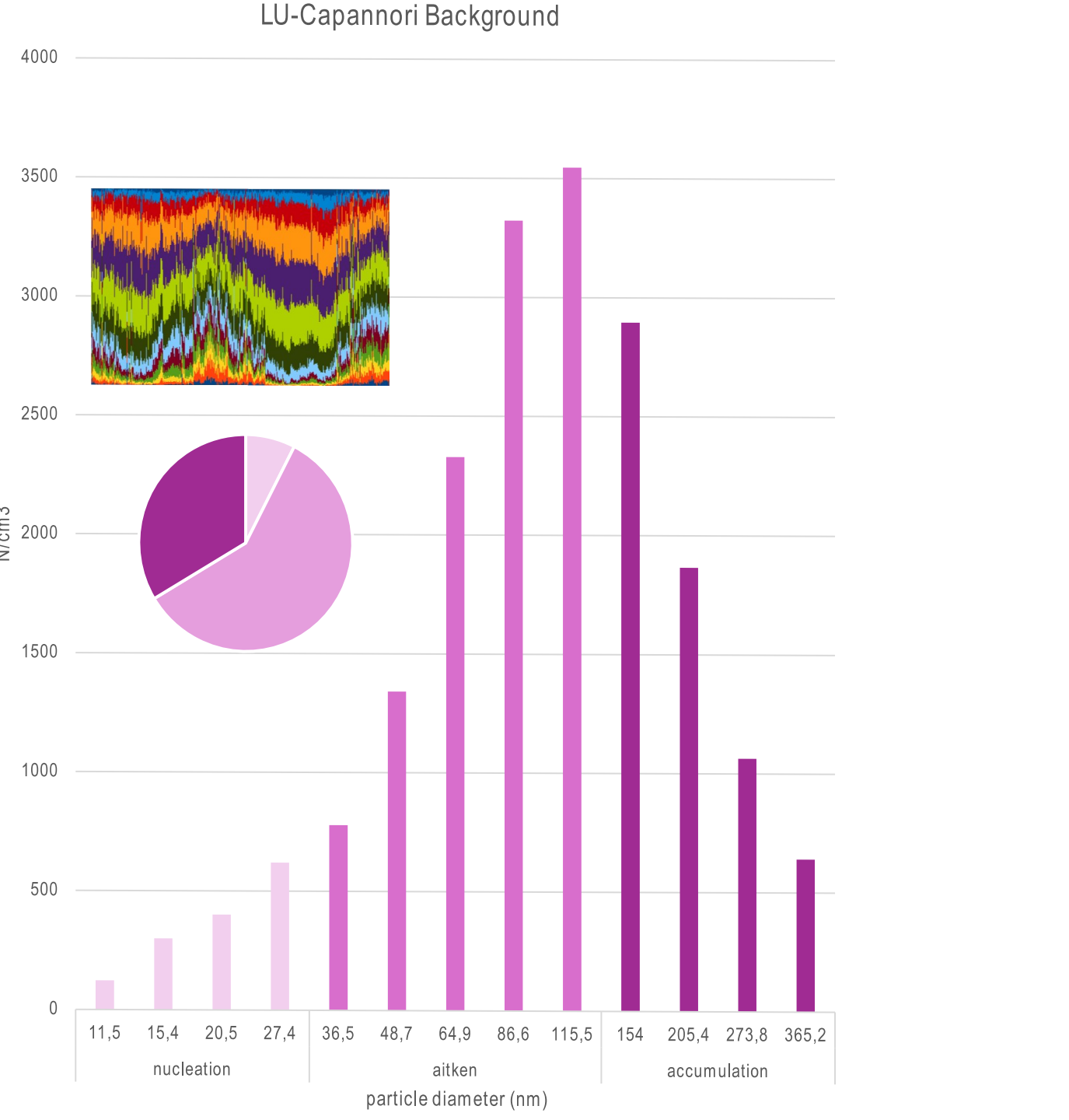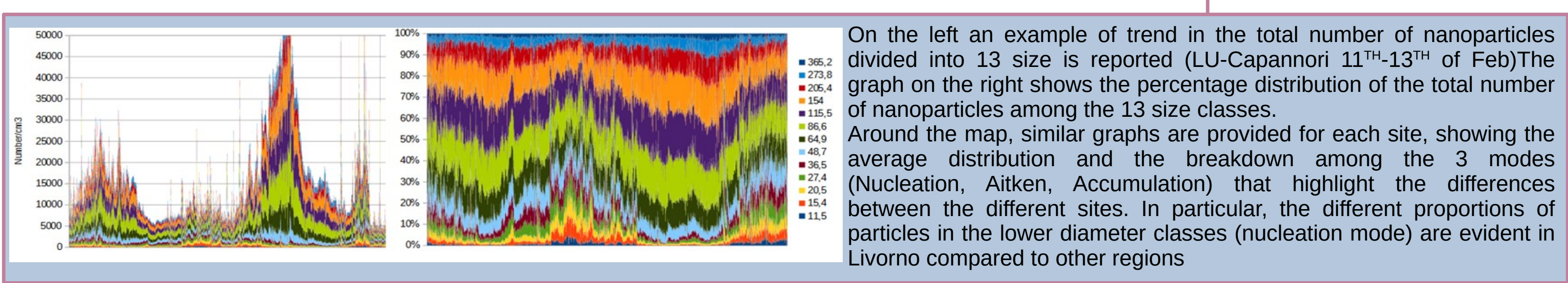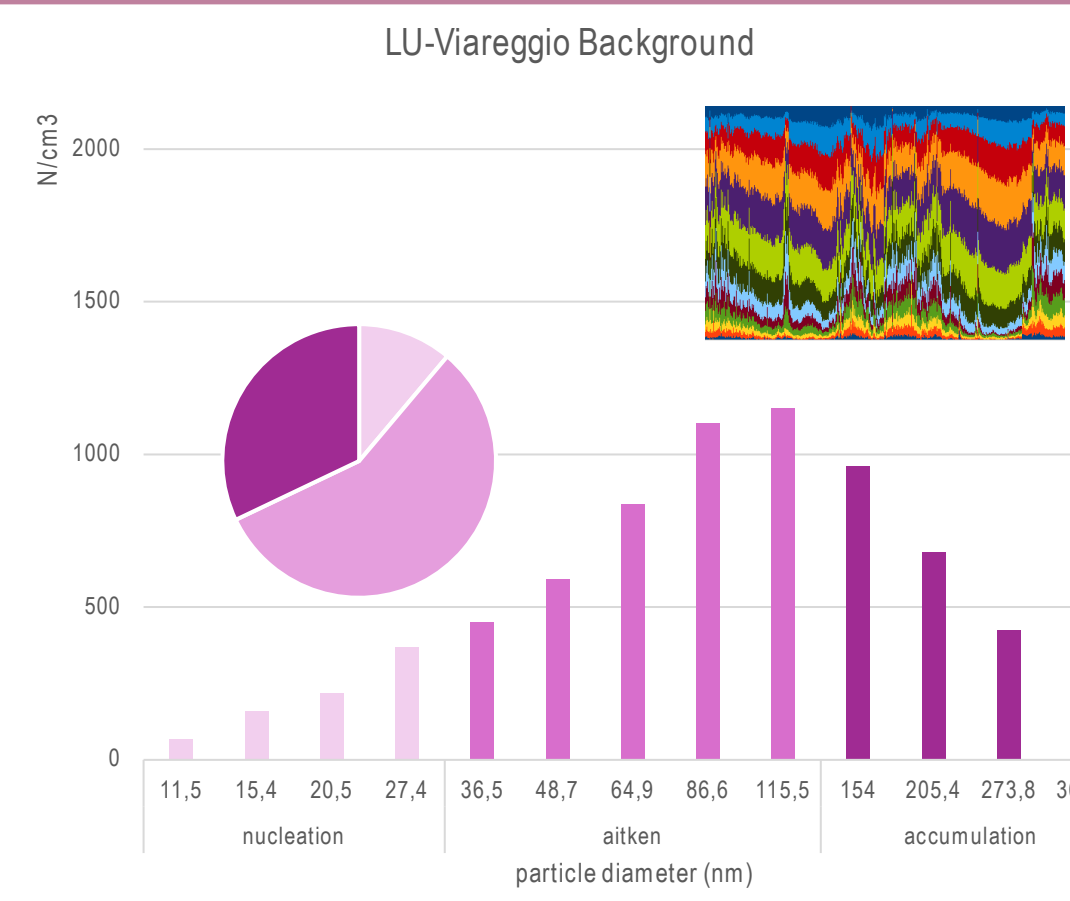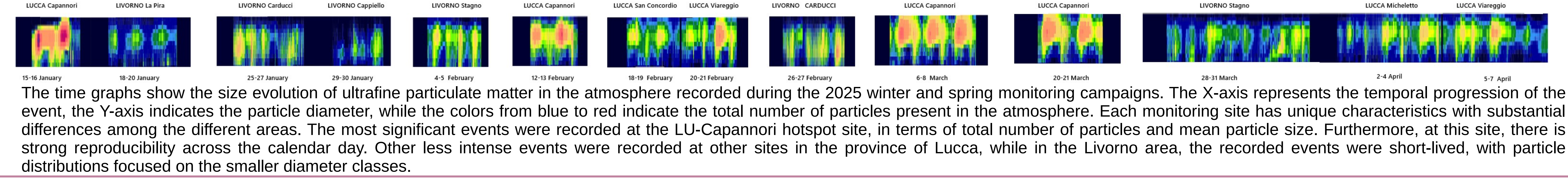
Regione Toscana

EAC 2025

INTRODUCTION The new European Air Quality Directive 2024/2881 [1] introduces new monitoring requirements. These include ultrafine particles (UFPs), for which monitoring is recommended at sites where high levels are expected, such as busy roads, ports, airports, and sites affected by biomass combustion. This study presents a screening monitoring of a subregion of Tuscany, provinces of Lucca and Livorno

- In winter 2025, UFP measurements were taken in the **city of Livorno**, which is known for its busy port and major industrial hub: **four sites**, one **traffic** site, one **background** site and two **industrial** sites near the refinery, so that the whole urban area of Livorno could be covered.
- The **Lucca Plain**, characterized by intensive use of biomass combustion for domestic heating was investigated in three **sites**: one **traffic** site and two **background** sites, one in the urban area of the city of Lucca and one in the urban area of Capannori, where the contribution of biomass burning is more significant. The last site studied in the province of Lucca is located in the municipality of **Viareggio**, a coastal background site also affected by biomass combustion.

Monitoring 2025 schedule table (Location, Site — JANUARY, FEBRUARY, MARCH, APRIL)
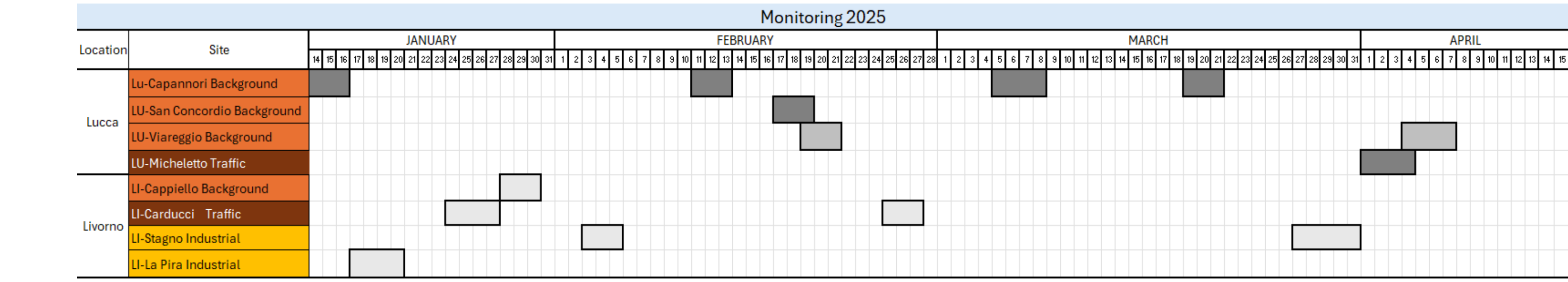
MATERIALS AND METHODS The instrument used is a **TSI Nanoscan 3910**, a portable size distribution instrument that provides particle concentrations in 13 size classes from 10 nm to 365 nm. Measurements were taken for short periods of time at each site (two to four days) and repeated cyclically over different months. Data were collected every minute in winter 2025 with last samplings in the very beginning of the spring.
The data were normalized to the total number of particles and the k-means method in R [2] was used, selecting 7 as number of clusters.

MONITORING RESULTS AND SPATIAL DISTRIBUTION

The time graphs show the size evolution of ultrafine particulate matter in the atmosphere recorded during the 2025 winter and spring monitoring campaigns. The X-axis represents the temporal progression of the event, the Y-axis indicates the particle diameter, while the colors from blue to red indicate the total number of particles present in the atmosphere. Each monitoring site has unique characteristics with substantial differences among the different areas. The most significant events were recorded at the LU-Capannori hotspot site, in terms of total number of particles and mean particle size. Furthermore, at this site, there is strong reproducibility across the calendar day. Other less intense events were recorded at other sites in the province of Lucca, while in the Livorno area, the recorded events were short-lived, with particle distributions focused on the smaller diameter classes.

On the left an example of trend in the total number of nanoparticles divided into 13 size is reported (LU-Capannori 11TH-13TH of Feb)The graph on the right shows the percentage distribution of the total number of nanoparticles among the 13 size classes.
Around the map, similar graphs are provided for each site, showing the average distribution and the breakdown among the 3 modes (Nucleation, Aitken, Accumulation) that highlight the differences between the different sites. In particular, the different proportions of particles in the lower diameter classes (nucleation mode) are evident in Livorno compared to other regions

Site	Average site N tot/cm3	% ore > 20000 N tot/cm3
Lu-Capannori Background	19228	34%
LU-San Concordio Background	5809	0%
LU-Viareggio Background	7274	4%
LU-Micheletto Traffic	5779	1%
LI-Cappiello Background	2838	0%
LI-Carducci Traffic	7851	4%
LI-Stagno Industrial	5675	1%
LI-La Pira Industrial	3174	0%

WHO reference [3]: hourly value 20000 N tot/cm3
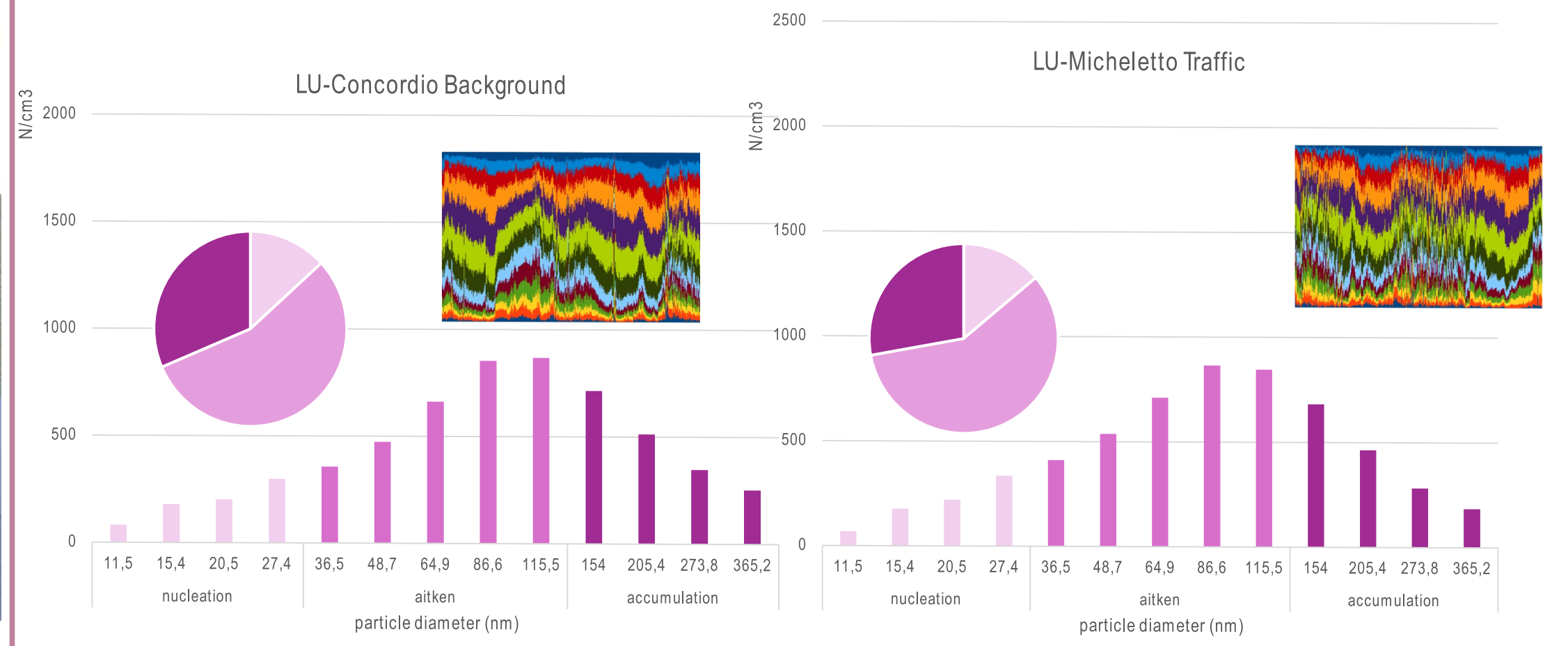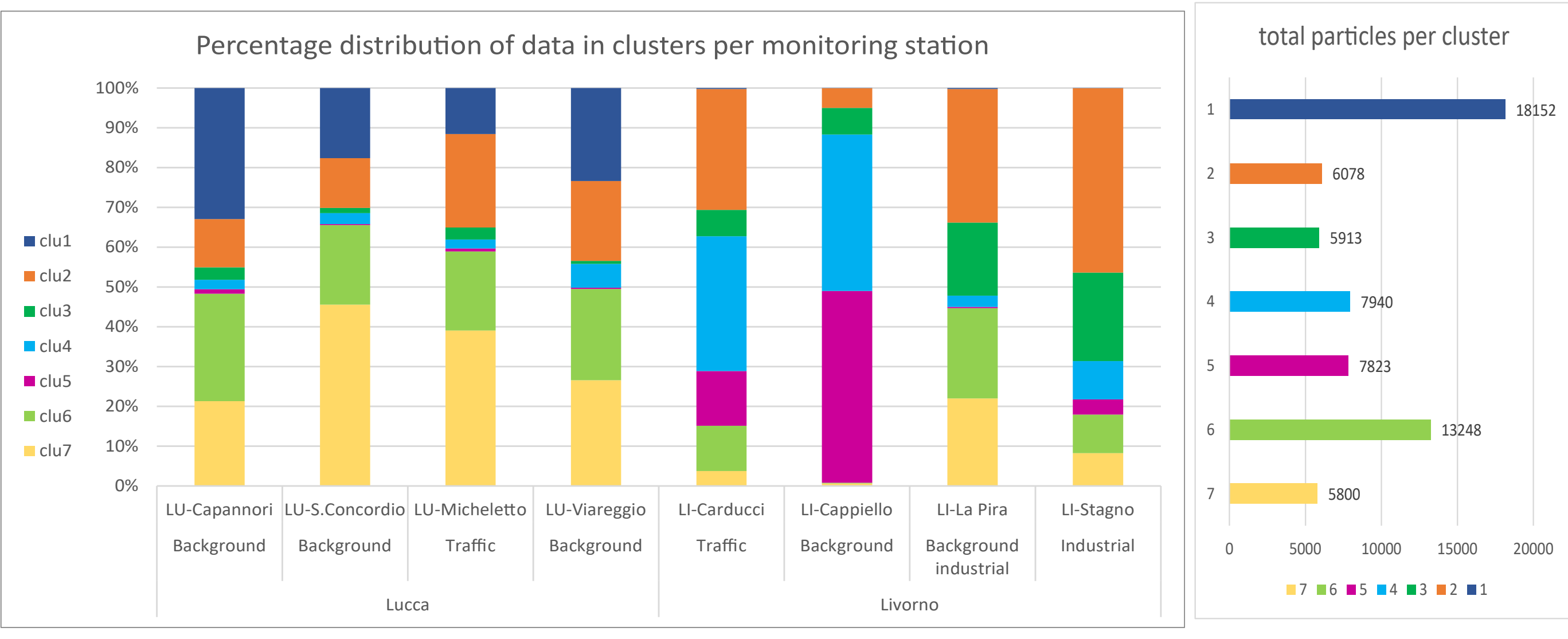
CLUSTER ANALYSIS
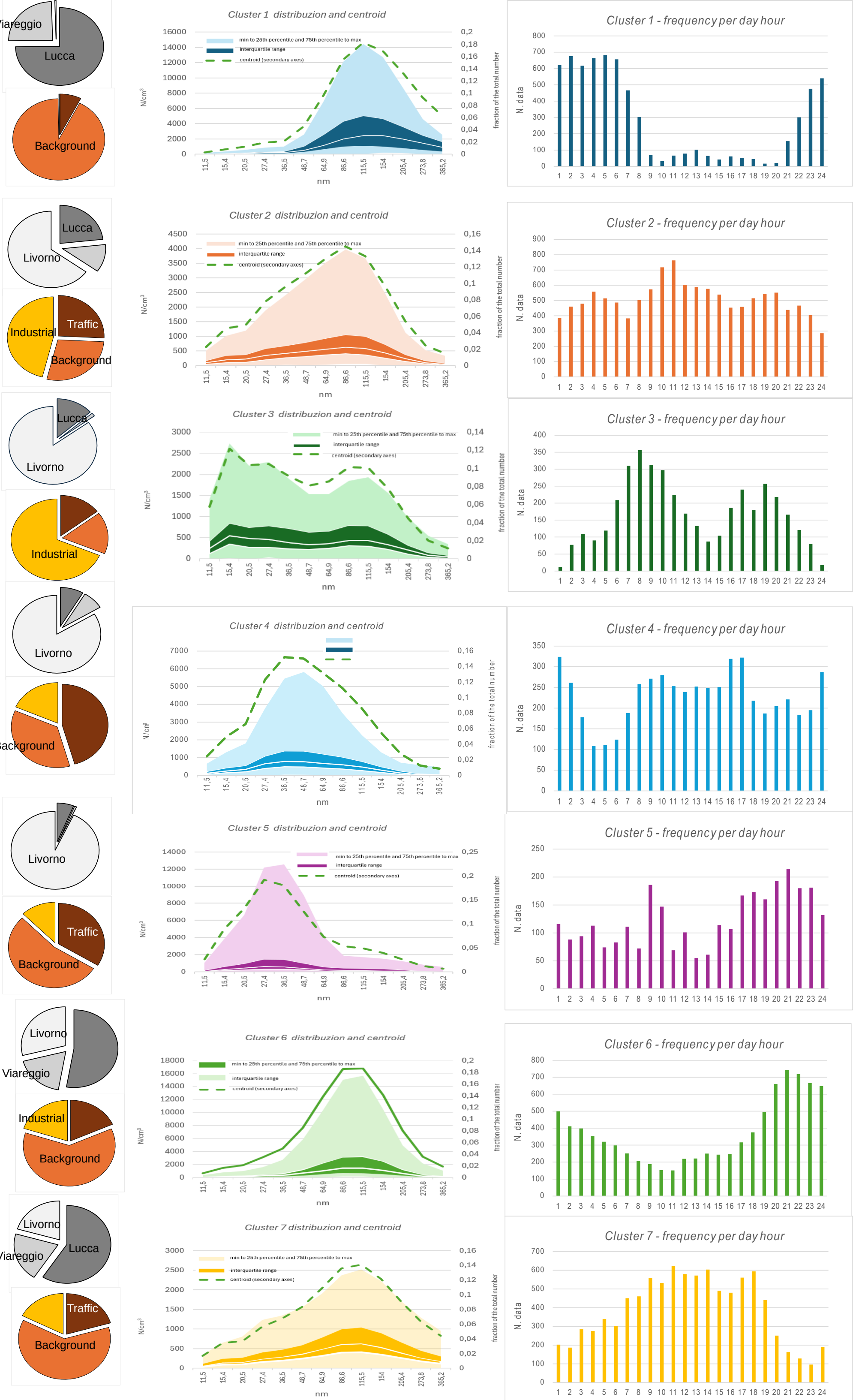
Cluster1 is present only in the Lucca area (background or traffic), including the coastal site of Viareggio. It is centered on the **115 nm** size class and occurs mainly at night. It can be clearly identified as the **biomass burning** cluster, typical of the entire Lucca area. (*PO1: 235 Monitoring of UFPs in a site affected by biomass burning* [4])

Cluster2-3 are prevalent in the coastal area of Livorno, particularly in the two "industrial background" sites (subject to spillover from the port and the refinery). In both clusters, the distribution includes more than one mode, representing the multiple sources affecting the sites. Cluster 2 is centered on the **86.6 nm** class, but shows other peaks in smaller diameter classes. The temporal distribution is fairly uniform, with a slightly higher frequency during the central morning hours. Cluster 3 still has the mode centered on **86.4–115.5 nm**, but the modes at **15.4 nm** and **27.4 nm** become more prominent. The temporal distribution indicates a closer correlation with **human activity**, with a higher daytime frequency during peak hours.

Cluster4-5 are relevant for only two monitoring sites, both in Livorno: LI-Carducci (a high-traffic site) and LI-Cappiello (a low-emission residential area). These two monitoring sites alone cover over 60% of the total presence of cluster 4 and over 80% of cluster 5. Cluster 4 does not exhibit a recognizable temporal pattern and is rather randomly distributed, while the temporal profile of cluster 5 may be related to peak traffic hours, with a morning peak around 9:00 AM. The trend of these two clusters is toward finer particles (cluster 4 peaks at **36–48 nm** and cluster **5 at 27–36 nm**), consistent with the production of fresh particles from a nearby source.

Cluster6-7 tend to be present in higher percentages at the inland sites of Lucca and at the coastal site of Viareggio, which more closely resembles the Lucca area than the sites on the Livorno coast. They can be assumed to be **secondary clusters** because they are in Aitken/accumulation mode and their temporal trends are almost inverse. For this reason, it can be assumed that Clu 6 is favored by the atmospheric stability typical of the nighttime hours, while Clu 7 is a secondary cluster favored by solar radiation during the daytime hours.

The graph below shows the results of clusterization in 7 cluster with percentage distribution of nanoparticles for each site surveyed, divided into the clusters identified and normalized for total particles. On the right side the average number of particles for each cluster are reported, calculated over the entire monitoring period. Clusters 1 and 6 have the greatest impact on the total number.

Percentage distribution of data in clusters per monitoring station

total particles per cluster:
1 — 18152
2 — 6078
3 — 5913
4 — 7940
5 — 7823
6 — 13248
7 — 5800

CONCLUSIONS

- Cluster analysis indicates that the distribution of nanoparticles depends much more on the area than on the type of site. Therefore, there are **clusters typical of the Livorno coastal area** and **clusters much more frequent in the Lucca hinterland**. The LU-Viareggio coastal background station shows behavior more similar to the stations in the Lucca plain than to those in Livorno, resulting strongly influenced by the sources characteristic of the Lucca area.
- There are no similarities between the two traffic stations because at LU-Micheletto (moderate traffic), the impact of the Lucca plain is stronger than that of the traffic source, which emerges at LI-Carducci (heavy traffic).
- All four stations in Lucca have similar distributions and differ only in the number of particles, which is significantly higher at the LU-Capannori hot spot than at the other sites.
- Nucleation classes composed of fresher particles that remain in the atmosphere for a shorter time are more significant in the coastal area of Livorno than in the Lucca area.
- The clusters of the two stations in the industrial area of Livorno (Li-La Pira and LI-Stagno)show a variety of distribution patterns, indicating the presence of multiple simultaneous sources. The other two coastal stations have very similar clusters except for the number of particles, which at LI-Carducci (UT) is significantly higher than at LI-Cappiello (UB).

REFERENCES
[1]DIRECTIVE (EU) 2024/2881 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on ambient air quality and cleaner air for Europe
[2] R Core Team (2023). R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria
[3] "WHO global air quality guidelines: Particulate matter (PM$_{2.5}$ and PM$_{10}$), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide", 2021
[4] Poster EAC 2025: PO1: 235 Monitoring of UFPs in a site affected by biomass burning