Response to Reviewer #1

Kanawade et al. reported the observation of an interesting phenomenon of nanoparticle shrinkage and explored the potential underlying mechanisms, which is different from the well-known U-shaped evolution of PNSD. Such a phenomenon has been reported in previous studies, yet this is the first time that the underlying processes are examined with the simultaneous measurements of particles, ions, and gaseous precursors. The authors proposed that these events were governed by atmospheric dilution, and reversible partitioning of LVOCs and SVOCs led to rapid nanoparticle shrinkage. Although the hypothesis can be valid and the manuscript is easy to follow, its evidence was organized in a perhaps unbalanced structure. Overall, I recommend the publication of this manuscript in Atmospheric Chemistry and Physics and hope the authors can address my comments below.

Response:

We thank the reviewer for their constructive suggestions and for acknowledging the novelty of the observations reported in this work, which aim to investigate the underlying processes of the nanoparticle shrinkage (NPS) phenomenon. We have revised the manuscript to improve the structure of the results and discussion section, moved the analysis of transport processes into the main text, and clarified the possible scenarios for the observed nucleation-mode particles during the NPS event. All author responses are marked in blue, and changes in the revised manuscript are indicated in red.

Major comments

1. The core analysis (Figs. 3-5 and related text) investigates potential causes of NPS events using gas and particulate data from the measurement site. However, as clearly indicated by the particle size distributions, new particles observed during NPS events did not originate at the observation site but were transported post-formation. The rapid shifts in size distributions further indicate a significant change in meteorological conditions/air masses. Given the geographical conditions of the Cyprus site, it is reasonable to anticipate a significant influence of transport on the observed particle evolution, whereas local measurements of precursors may not be sufficient to explain particle formation. Therefore, I recommend the following structure of the results and discussion section:

a) Analyzing particle origins via meteorological parameters and back-trajectory analysis. Current discussions are mainly in in the SI (with discussions on anthropogenic tracers in main text). The analysis should be enhanced with a focus on the short periods when the shift in size distribution were observed.

b) Investigating rapid particle shrinkage through local precursor observations and particle size evolution analysis.

Response:

We agree with the reviewer that the influence of long-range transport is important for interpreting the observed particle evolution. In the original manuscript, trajectory analyses, together with vertical velocity and specific humidity parameters, were presented in the Supplementary Information; these have now been moved to the main text.

Following the reviewer's suggestion, we have subdivided Section 3.2 (*Elucidating a nanoparticle shrinkage event*) into three parts. First, we present particle size distributions and aerosol properties, as in the original manuscript (Section 3.2.1). Second, we examine the influence of meteorological conditions and air-mass transport, as suggested by the reviewer, together with the dynamic state and anthropogenic tracers (Section 3.2.2). Finally, we discuss the potential role of precursor gases and condensing vapors to assess the chemical processes responsible for the nanoparticle shrinkage phenomenon.

We agree that particle formation may have occurred upwind and that the nanoparticles were subsequently transported to the measurement site and downwind. This can be investigated in two ways. The first, more resource-intensive, approach involves simultaneous measurements of particle size distributions at multiple stationary sites along the air-mass transport pathway. However, such measurements were not available for locations upwind (or downwind) of our site (CAO-AMX). In our recent study, using simultaneous measurements from a low-altitude (CAO-AMX) and a high-altitude site (Troodos, CAO-TRO), we showed that approximately half of the observed events at both sites occurred concurrently along the same air-mass pathway, under the influence of an evolving planetary boundary layer (Deot et al., 2025).

The second, and more commonly used, approach is to estimate the spatial extent of the event using the method of Hussein et al. (2009). This method uses hourly calculated air-mass backward trajectories to infer how far upwind of the measurement site the events may have been triggered. Our analysis shows that both event types (NPF and NPS) have similar spatial scales, on the order of 50-200 km. This relatively large extent is consistent with our findings that the observed particles are not formed locally; therefore, particle formation occurring upwind of the measurement site on the NPS event day is possible.

We have thoroughly revised the discussion of the influence of meteorological conditions and air-mass transport, including analyses of the spatial extent of the events (a corresponding figure has also been added to the Supplementary Information).

Previous studies have shown that variations in air-mass origin, transport pathways, atmospheric dilution, vertical mixing, and the mixing of different air-masses can strongly influence the occurrence and evolution of NPF events (Kulmala et al., 2004; Kanawade et al., 2012; Nilsson et al., 2001; Hussein et al., 2009; Tunved et al., 2004). Air-mass trajectory analysis reveals distinct transport pathways and air-mass characteristics between the two cases, particularly on 6 and 7 April (Fig. 5a). During the NPF event, air masses traveled slowly near the ocean surface and largely remained within the PBL. In contrast, during the NPS event, the air masses traveled fast and descended from the free troposphere to near-surface levels during the passage over the Western Taurus mountain range (Fig. 5a). A similar contrast in air-mass history between NPF and NPS events was observed for the 10-11 April case (Fig. S6a). While the air masses traveled within the PBL during both the NPF and NPS events for the 20-21 April case (Fig. S7a), air masses traveled fast near the ocean surface on 21 April (NPS event).

To further assess the dynamic state of the lower atmosphere, vertical velocity and specific humidity were examined (Fig. 5b-c). Stronger low-level subsidence, accompanied by lower specific humidity (i.e., drier air), was evident in the upwind region of the measurement site on NPS event days (Fig. 5c), indicating the intrusion of drier air masses from higher altitudes. Such enhanced vertical mixing and entrainment of cleaner, drier free tropospheric air are indicative of atmospheric dilution and are consistent with the observed lower near-surface aerosol mass (Fig. 6a-b) and reduced columnar aerosol loading (Fig. 6c), as well as lower NO_x (Fig. 6d) and carbon monoxide (CO; Fig. 6e). Fast-moving air-masses accompanied by strong winds can enhance turbulent mixing, leading to dilution of particle concentrations and changes in particle size distributions (Shi et al., 1999), which is evident during NPS events (Fig 5a and Figs. S6-S7). Furthermore, the observed nucleation mode particles may originate from NPF occurring upwind of the measurement site and subsequently advected to the site, or from overlapping nucleation modes arising from distinct nearby anthropogenic sources (Hakala et al., 2023; Kivekäs et al., 2016). As discussed earlier, anthropogenic sources upwind of the measurement site are minimal (Fig. 3f); thus, the advection of nucleation-mode particles directly from primary emissions is unlikely to explain the observed nucleation mode particles during the NPS event.

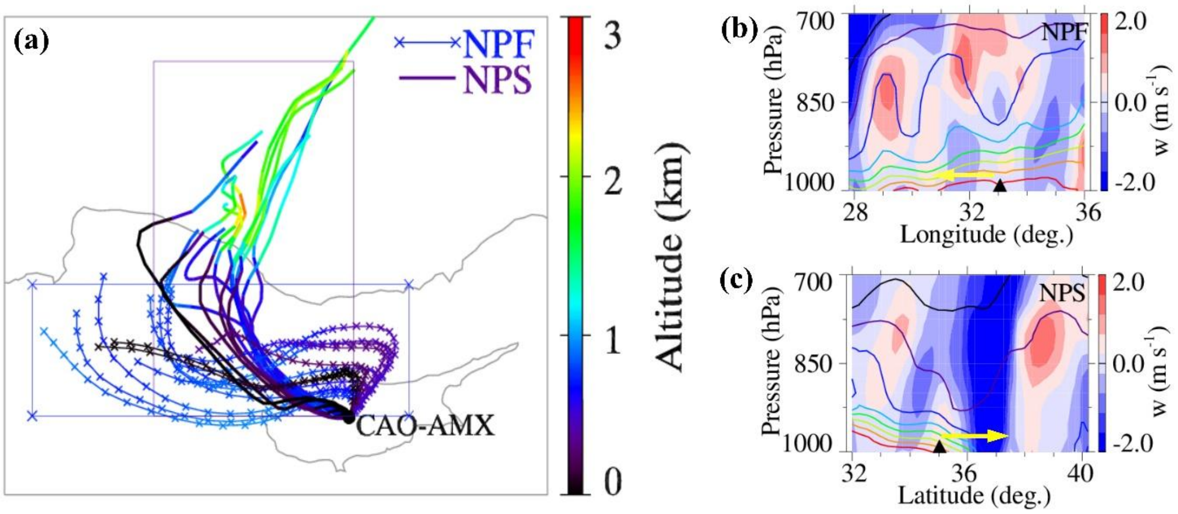

Figure 5: 48-hour air-mass backward trajectories (00-12 UTC) as a function of altitude, initialized at 500 meters above ground level at the AMX site during the NPF event (6 April, line connected by a cross symbol) and the NPS event (7 April, solid lines. The region shown by the rectangular box is used to create longitude (latitude)-altitude cross-sections of averaged (b-c) vertical velocity (w, filled contours) along air-mass trajectories over 0-9 UTC for NPF and NPS event days observed on 6 April and 7 April, respectively. Contour lines represent specific humidity of 2, 3, 4, 5, 6, 7, 8, and 10 g kg^{-1}, shown in black, violet, blue, cyan, green, yellow, orange, and red, respectively. The negative value of w indicates subsidence, while the positive values indicate the updraft. The yellow-colored arrows indicate the upwind region of the measurement site.

The origin of the observed nanoparticles during NPS event days can be constrained into three physically consistent scenarios: the particles were either transported from nearby anthropogenic sources or formed upwind of the measurement site and subsequently advected to the site or formed locally but failed to grow. The low BC mass concentrations (Figs. 3f, 6a), together with reduced NO_x (Fig. 6d) and CO (Fig. 6e) levels, suggest that contributions from overlapping nucleation modes arising from nearby anthropogenic sources (Hakala et al., 2023; Kivekäs et al., 2016) are unlikely to explain the observed nucleation mode particles during the NPS event. Instead, these particles are more likely to be formed upwind of the site and subsequently transported to the observation location. It is therefore critical to constrain the spatial extent of over which particle formation occurs. Two approaches are commonly used to estimate this extent. The first, and more resource-intensive, approach relies on simultaneous measurements of particle size distributions at multiple stationary sites along the air-mass transport pathway. The second approach is based on hourly calculated backward air-mass trajectories. As no simultaneous measurements were available at the upwind locations of the measurement site, the spatial extent of the observed NPF and NPS events was estimated based on backward air-mass trajectory analysis, following the methodology of Hussein et al. (2009). This analysis reveals similar spatial scales for both event types (NPF and NPS; approximately 50-200 km, Fig. S8), with NPS events occurring along similar air-mass path. This suggests that particle formation occurring upwind of the measurement site on NPS event days is plausible. In our recent study, using simultaneous measurements from a low-altitude site (CAO-AMX) and a high-altitude site (Troodos, CAO-TRO), we showed that approximately half of the observed NPF events at both sites occurred concurrently along the same air-mass pathway, under the influence of an evolving planetary boundary layer height (Deot et al., 2025). The lower number concentrations of negative ions in 2.0-2.3 nm size range (Fig. 6g), sub-3nm neutral particles (Fig. 6h), and negative particles in the 2.5-7 nm (Fig 6i) and 7-25 nm (Fig 6j) size range on NPS event days can be attributed to reduced levels of condensing vapours (discussed in Section 3.2.3), together with a lower condensation sink (Fig. 6k) and a lower particle volume concentration (Fig. 6l).

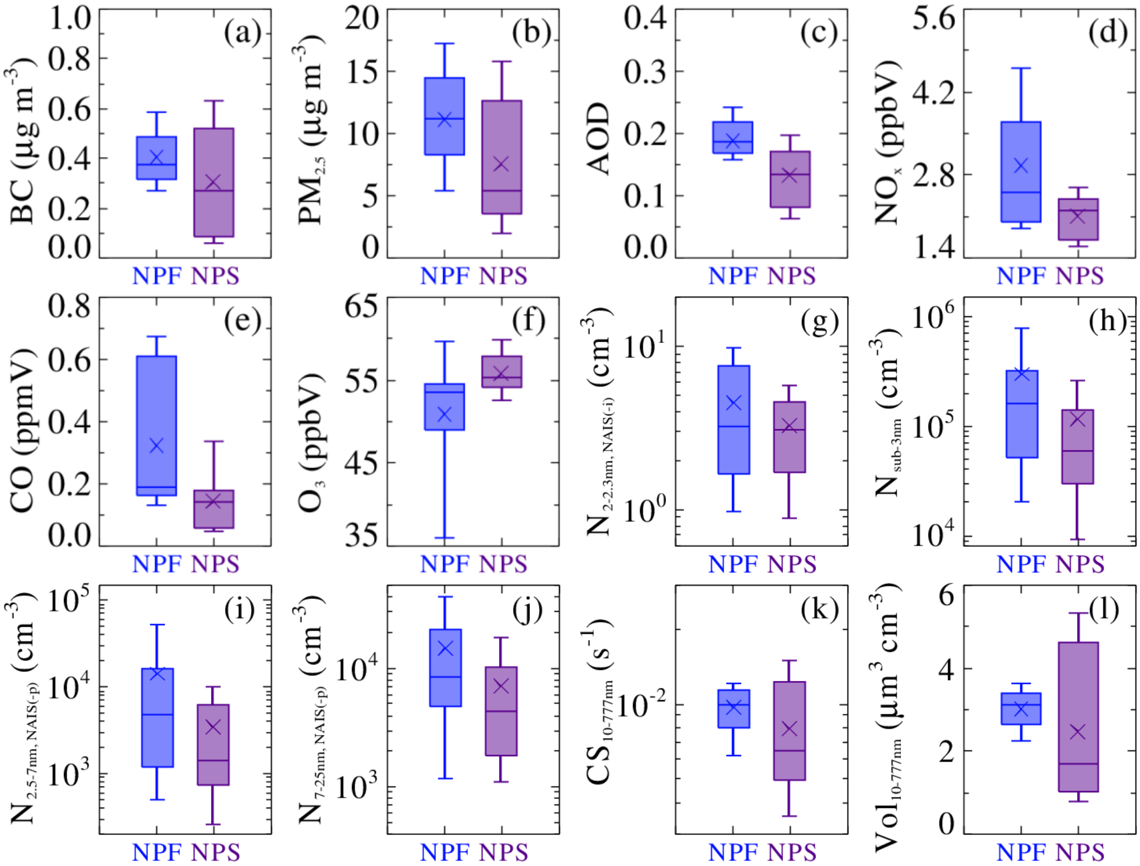

Figure 6: Key differences in aerosols, gases and nanoparticles averaged over the observed NPF (6, 10, and 20 April) and NPS (7, 11, and 21 April) event days. Box–whisker plots show (a) black carbon (BC) mass concentrations, (b) particulate matter with an aerodynamic diameter less than 2.5 μm ($PM_{2.5}$), (c) aerosol optical depth (AOD), (d) oxides of nitrogen (NO_x), (e) carbon monoxide (CO), (f) ozone (O_3), (g) negative ions in the 2.0–2.3 nm size range, (h) sub-3nm particles, (i) negative particles in the 2.5–7.0 nm size range, (j) negative particles in the 7.0–25 nm size range, (k) total condensation sink ($CS_{10\text{-}777nm}$), and (l) total particle volume concentration. Data correspond to the 06–12 UTC period. The cross symbol indicates the mean, the horizontal line indicates the median, the bottom and top of the box indicate the 25th and 75th percentiles, and the bottom and top of the whisker indicate the 10th and 90th percentiles.

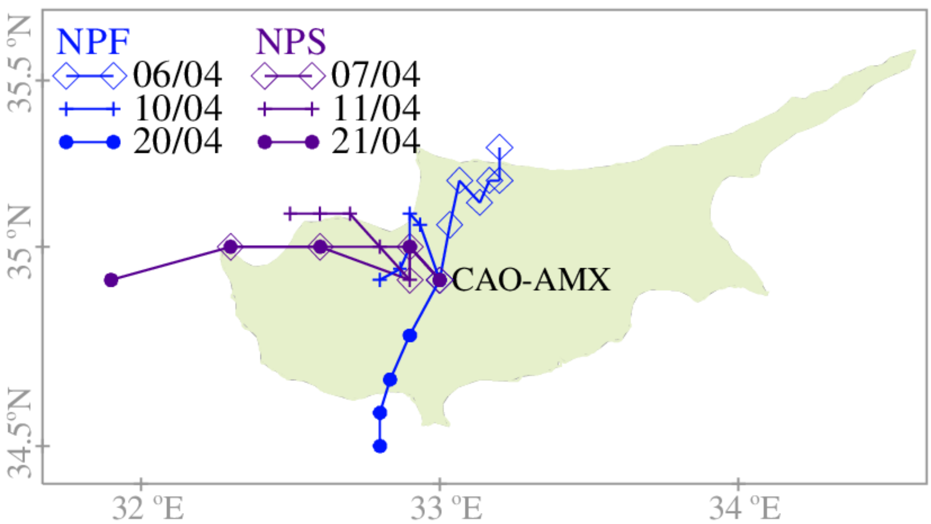

Figure S8. Spatial extent of the observed NPF (blue lines) and NPS (purple lines) events. The spatial coverage of each event was estimated using hourly air-mass backward trajectories following the methodology described by Hussein et al. (2009). For each event, the starting time was defined as 06:00 UTC and the ending time as 12:00 UTC, based on the visualization of contour plots of particle size distribution from the NAIS (Fig. 3b). Hourly backward air-mass trajectories were traced in the upwind direction between 6:00 and 12:00 UTC, representing the possible regions where the event may have been triggered. Each trajectory represents the approximate geographical coverage of an event.

2. Beyond NPS events, what causes particle shrinkage in DMD events? Could this contribute to elucidate the NPS phenomena?

Response:

As explained in the Introduction section, DMD events are characterized by an initial increase in the modal diameter of nucleation-mode particles formed during NPF into the Aitken-mode size range, followed by a subsequent decrease to smaller sizes (Kamra et al., 2022; Hakala et al., 2019; Alonso-Blanco et al., 2017; Salma et al., 2016; Skrabalova et al., 2015; Cusack et al., 2013; Young et al., 2013; Yao et al., 2010; Backman et al., 2012; Hussein et al., 2020; Zhang et al., 2016; Yue et al., 2016; Kivekäs et al., 2016). In contrast, NPS events occur without any preceding particle formation or growth. Hakala et al. (2023) attributed DMD events to low-growth environments associated with reduced photochemical productions of condensable vapors and air mass history; however, we did not observe particle growth during the NPS events.

In this work, we focus explicitly on newly observed nanoparticle shrinkage phenomena, which differ from previously reported DMD events in several key aspects. First, NPS events occur without preceding NPF or local particle formation. Second, the shrinkage is confined to particles in the sub-20 nm size range. Third, these events are closely associated with atmospheric dilution driven by the entrainment of cleaner free-tropospheric air or enhanced turbulent mixing within the fast-moving air masses.

3. The evaporation discussion appears contradictory. It is stated that “observed differences in particle behavior were not driven by the availability of condensing vapours......” However, particle shrinkage is latter attributed to “evaporation of condensable species under atmospheric dilution”. If vapor concentrations do not govern gas-particle equilibrium, what are the governing factors (e.g., temperature, particle size)? Please elaborate; alternatively, please consider softening or removing relevant sentences in the abstract and conclusions.

Response:

We thank the reviewer for highlighting this contradictory discussion. NPS events are not primarily driven by low concentrations of condensable vapors (reduced photochemical activities), their scavenging by pre-existing particles, or primary source of nanoparticles as in case of typical DMD events. Instead, our observations suggest that these events are closely linked to atmospheric dilution processes, whereby the entrainment of cleaner air masses and enhanced turbulent mixing alter the aerosol population, leading to the observed particle shrinkage behaviour. We have removed the contradictory statement in the discussion and revised relevant statements in the abstract and conclusions.

Atmospheric dilution reduces particle-phase organic mass and the associated absorptive capacity of the aerosol population, thereby shifting gas-particle partitioning towards the vapor phase (Pankow, 1994; Donahue et al., 2006). Under such conditions, semi-volatile organic compounds evaporate from nanoparticles even when gas-phase concentrations remain relatively high, as equilibrium is governed not only by vapor concentrations but also by particle-phase composition, size-dependent effects (e.g., Kelvin effect), and thermodynamic constraints (Riipinen et al., 2011; Seinfeld and Pandis, 2016).

We have revised the statements in the Abstract and Conclusions sections as below.

Abstract: We identified three NPS events during the campaign and show that this phenomenon is not primarily driven by low concentrations of condensable vapours, their scavenging by pre-existing particles, or primary nanoparticle sources. Instead, it is associated with atmospheric dilution, as indicated by air-mass trajectory analysis. Fast-moving air masses can enhance turbulent mixing, leading to dilution of particle number concentrations and changes in particle size distributions. Together with volatility-resolved analysis, these results suggest that NPS is governed by atmospheric dilution, which reduces particle-phase organic mass and shift the gas-particle equilibrium toward evaporation, with contributions dominated by organic compounds of low and moderate volatility.

Conclusions: The similar spatial scales of these events suggest that the sub-20nm particles likely originated from particle formation occurring upwind of the measurement site. These events were further characterized by fast-moving air masses, which can enhance turbulent mixing, leading to dilution of particle concentrations and changes in particle size distributions. Such conditions reduce organic aerosol mass and shifts gas-particle equilibrium towards evaporation. Volatility-resolved analysis further indicated a dominance of organic compounds of low and moderate volatility. Although ULVOCs and ELVOCs concentrations were slightly higher during NPS events, particle formation and subsequent growth remained inhibited, supporting net evaporation and leading to rapid particle shrinkage.

Response to Reviewer #2

General
The authors present a set of three nanoparticle shrinkage (NPS) events at rural Cyprus during a 2,5 Month measurement campaign. Even though such events were few during the campaign, previous measurements at the same site show that the phenomenon occurs repeatedly at the site, especially in April. To the authors' (and to the reviewer's) knowledge such events have not been reported or analyzed earlier in the literature. Therefore, the topic of the manuscript is both relevant and new.

Both new particle formation (NPF) and NPS events are relatively short (only 5-8 hours) before they become hard to follow. This is expected, considering the site being on a large island. Particles originating from further away come through very different conditions.
Response:
We thank the reviewer for their constructive suggestions and acknowledging the relevance of new observations. We have revised the manuscript to emphasize the role of air-mass variability in shaping the observed particle evolution in the main text. All author responses are marked in blue, and changes in the revised manuscript are indicated in red.

Analysis and conclusions
The set of instruments used at the measurement campaign is comprehensive, allowing a proper analysis of the events, and enabling confirming or ruling out of several hypothesis. Part of the relevant information is unfortunately in the supplementary material instead of the main manuscript.
Response:
We agree with the reviewer, and, as also indicated by the reviewer #1, we have moved the air-mass transport analysis to the main text. We have further subdivided Section 3.2 (*Elucidating a nanoparticle shrinkage event*) into three parts. First, we present particle size distributions and aerosol properties (Section 3.2.1). Second, we examine the influence of meteorological conditions and air-mass transport, together with the dynamic state of the atmosphere and anthropogenic tracers (Section 3.2.2). Finally, we discuss the role of precursor gases and condensing vapors to assess the possible chemical processes responsible for the nanoparticle shrinkage phenomenon.

The authors conclude that the particles observed during NPS events are not emitted as (anthropogenic) primary particles locally. However, the possibility of the particles originating via NPF upwind of the measurement site and advecting to the site (Kivekäs et al., 2016, Hakala et al., 2023) is not thoroughly examined. Analysis of trajectories in the main manuscript would provide valuable information here.
Response:
As also suggested by the reviewer #1, we agree that particle formation may have occurred upwind and that the nanoparticles were subsequently transported to the measurement site. This can be investigated in two ways. The first, more resource-intensive, approach involves simultaneous measurements of particle size distributions at multiple stationary sites along the air-mass transport pathway. However, such measurements were not available for locations upwind (or downwind) of our site (CAO-AMX). In our recent study, using simultaneous measurements from a low-altitude (CAO-AMX) and a high-altitude site (Troodos, CAO-TRO), we showed that approximately half of the observed events at both sites occurred concurrently along the same air-mass pathway, under the influence of an evolving planetary boundary layer (Deot et al., 2025).

The second, and more commonly used, approach is to estimate the spatial extent of the event using the method of Hussein et al. (2009). This method uses hourly calculated air-mass backward trajectories to infer how far upwind of the measurement site the events may have been triggered. Our analysis shows that both event types (NPF and NPS) have similar spatial scales, on the order of 50-200 km. This relatively large extent is consistent with our findings that the observed particles are not formed locally; therefore, particle formation occurring upwind of the measurement site on the NPS event day is plausible.

We agree with the reviewer that the air-mass trajectory analysis provides valuable information, which has now been moved to the main text.

Previous studies have shown that variations in air-mass origin, transport pathways, atmospheric dilution, vertical mixing, and the mixing of different air-masses can strongly influence the occurrence and evolution of NPF events (Kulmala et al., 2004; Kanawade et al., 2012; Nilsson et al., 2001; Hussein et al., 2009; Tunved et al., 2004). Air-mass trajectory analysis reveals distinct transport pathways and air-mass characteristics between the two cases, particularly on 6 and 7 April (Fig. 5a). During the NPF event, air masses traveled slowly near the ocean surface and largely remained within the PBL. In contrast, during the NPS event, the air masses traveled fast and descended from the free troposphere to near-surface levels during the passage over the Western Taurus mountain range (Fig. 5a). A similar contrast in air-mass history between NPF and NPS events was observed for the 10-11 April case (Fig. S6a). While the air masses traveled within the PBL during both the NPF and NPS events for the 20-21 April case (Fig. S7a), air masses traveled fast near the ocean surface on 21 April (NPS event).

To further assess the dynamic state of the lower atmosphere, vertical velocity and specific humidity were examined (Fig. 5b-c). Stronger low-level subsidence, accompanied by lower specific humidity (i.e., drier air), was evident in the upwind region of the measurement site on NPS event days (Fig. 5c), indicating the intrusion of drier air masses from higher altitudes. Such enhanced vertical mixing and entrainment of cleaner, drier free tropospheric air are indicative of atmospheric dilution and are consistent with the observed lower near-surface aerosol mass (Fig. 6a-b) and reduced columnar aerosol loading (Fig. 6c), as well as lower NO_x (Fig. 6d) and carbon monoxide (CO; Fig. 6e). Fast-moving air-masses accompanied by strong winds can enhance turbulent mixing, leading to dilution of particle concentrations and changes in particle size distributions (Shi et al., 1999), which is evident during NPS events (Fig 5a and Figs. S6-S7). Furthermore, the observed nucleation mode particles may originate from NPF occurring upwind of the measurement site and subsequently advected to the site, or from overlapping nucleation modes arising from distinct nearby anthropogenic sources (Hakala et al., 2023; Kivekäs et al., 2016). As discussed earlier, anthropogenic sources upwind of the measurement site are minimal (Fig. 3f); thus, the advection of nucleation-mode particles directly from primary emissions is unlikely to explain the observed nucleation mode particles during the NPS event.

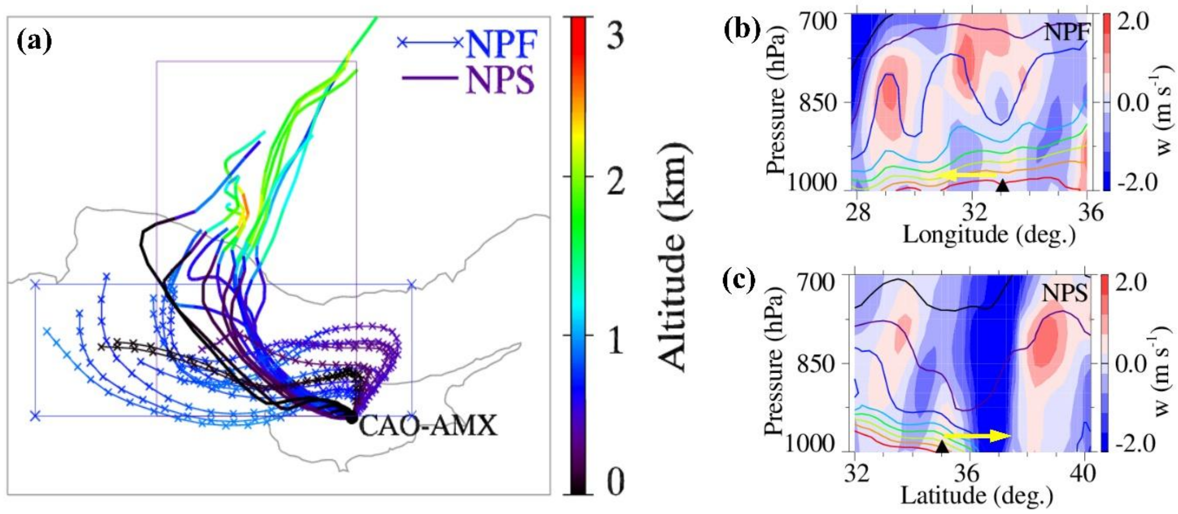

Figure 5: 48-hour air-mass backward trajectories (00-12 UTC) as a function of altitude, initialized at 500 meters above ground level at the AMX site during the NPF event (6 April, line connected by a cross symbol) and the NPS event (7 April, solid lines. The region shown by the rectangular box is used to create longitude (latitude)-

altitude cross-sections of averaged (b-c) vertical velocity (w, filled contours) along air-mass trajectories over 0-9 UTC for NPF and NPS event days observed on 6 April and 7 April, respectively. Contour lines represent specific humidity of 2, 3, 4, 5, 6, 7, 8, and 10 g kg^{-1}, shown in black, violet, blue, cyan, green, yellow, orange, and red, respectively. The negative value of w indicates subsidence, while the positive values indicate the updraft. The yellow-colored arrows indicate the upwind region of the measurement site.

The origin of the observed nanoparticles during NPS event days can be constrained into three physically consistent scenarios: the particles were either transported from nearby anthropogenic sources or formed upwind of the measurement site and subsequently advected to the site or formed locally but failed to grow. The low BC mass concentrations (Figs. 3f, 6a), together with reduced NO_x (Fig. 6d) and CO (Fig. 6e) levels, suggest that contributions from overlapping nucleation modes arising from nearby anthropogenic sources (Hakala et al., 2023; Kivekäs et al., 2016) are unlikely to explain the observed nucleation mode particles during the NPS event. Instead, these particles are more likely to be formed upwind of the site and subsequently transported to the observation location. It is therefore critical to constrain the spatial extent of over which particle formation occurs. Two approaches are commonly used to estimate this extent. The first, and more resource-intensive, approach relies on simultaneous measurements of particle size distributions at multiple stationary sites along the air-mass transport pathway. The second approach is based on hourly calculated backward air-mass trajectories. As no simultaneous measurements were available at the upwind locations of the measurement site, the spatial extent of the observed NPF and NPS events was estimated based on backward air-mass trajectory analysis, following the methodology of Hussein et al. (2009). This analysis reveals similar spatial scales for both event types (NPF and NPS; approximately 50-200 km, Fig. S8), with NPS events occurring along similar air-mass path. This suggests that particle formation occurring upwind of the measurement site on NPS event days is plausible. In our recent study, using simultaneous measurements from a low-altitude site (CAO-AMX) and a high-altitude site (Troodos, CAO-TRO), we showed that approximately half of the observed NPF events at both sites occurred concurrently along the same air-mass pathway, under the influence of an evolving planetary boundary layer height (Deot et al., 2025). The lower number concentrations of negative ions in 2.0-2.3 nm size range (Fig. 6g), sub-3nm neutral particles (Fig. 6h), and negative particles in the 2.5-7 nm (Fig 6i) and 7-25 nm (Fig 6j) size range on NPS event days can be attributed to reduced levels of condensing vapours (discussed in Section 3.2.3), together with a lower condensation sink (Fig. 6k) and a lower particle volume concentration (Fig. 6l).

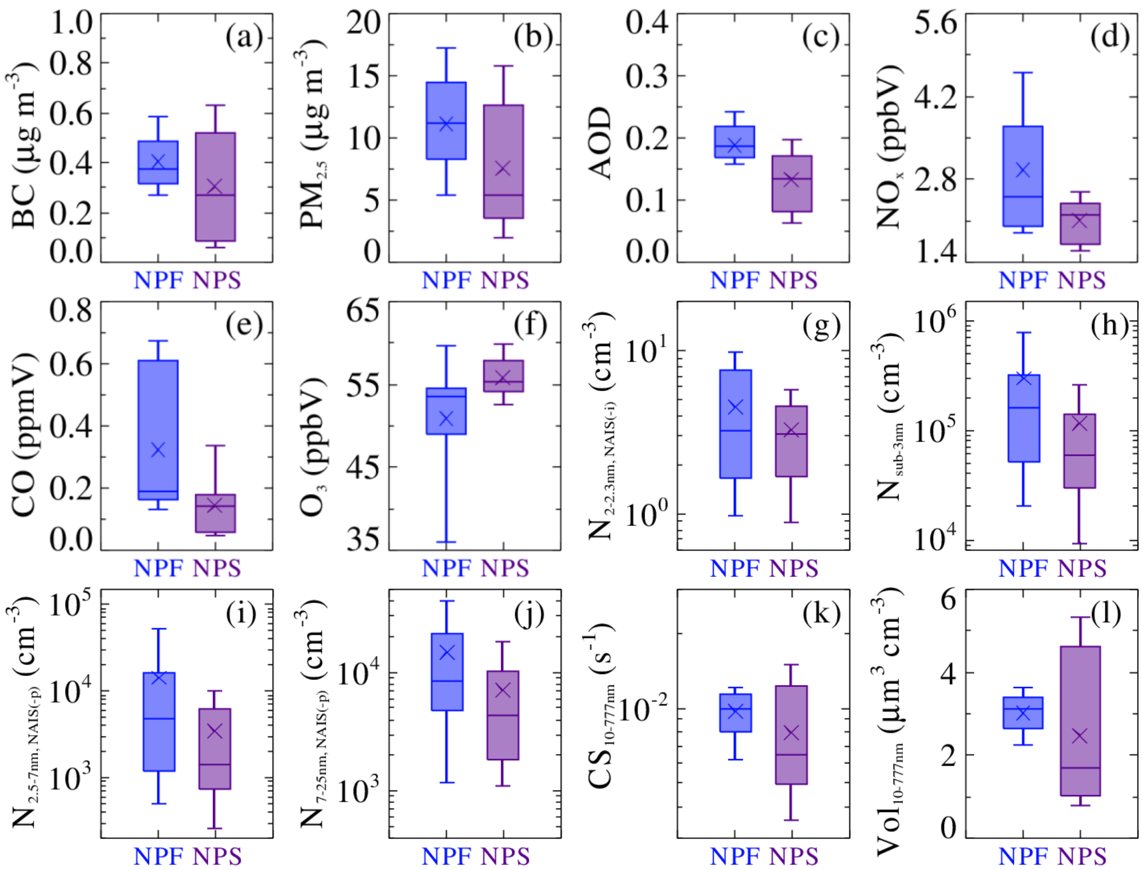

Figure 6: Key differences in aerosols, gases and nanoparticles averaged over the observed NPF (6, 10, and 20 April) and NPS (7, 11, and 21 April) event days. Box–whisker plots show (a) black carbon (BC) mass concentrations, (b) particulate matter with an aerodynamic diameter less than 2.5 µm ($PM_{2.5}$), (c) aerosol optical depth (AOD), (d) oxides of nitrogen (NO_x), (e) carbon monoxide (CO), (f) ozone (O_3), (g) negative ions in the 2.0–2.3 nm size range, (h) sub-3nm particles, (i) negative particles in the 2.5–7.0 nm size range, (j) negative particles in the 7.0–25 nm size range, (k) total condensation sink ($CS_{10\text{-}777nm}$), and (l) total particle volume concentration. Data correspond to the 06–12 UTC period. The cross symbol indicates the mean, the horizontal line indicates the median, the bottom and top of the box indicate the 25th and 75th percentiles, and the bottom and top of the whisker indicate the 10th and 90th percentiles.

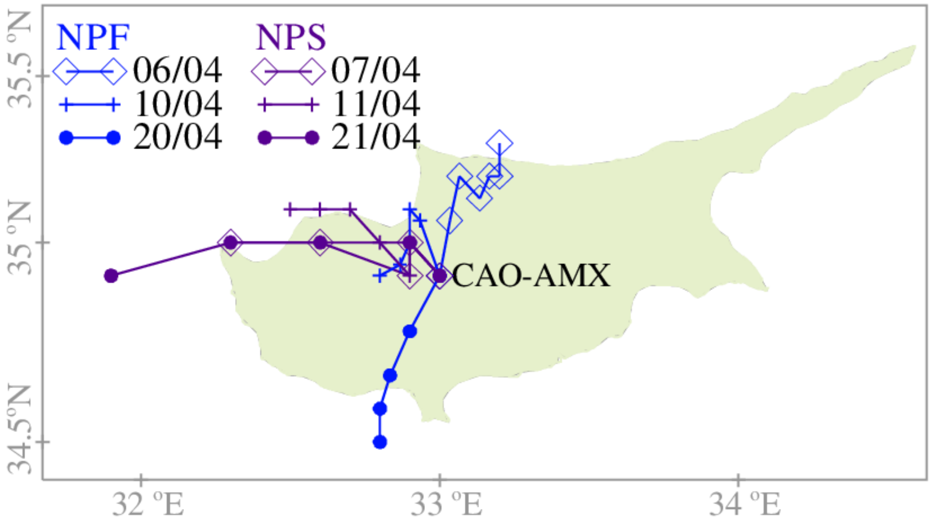

Figure S8. Spatial extent of the observed NPF (blue lines) and NPS (purple lines) events. The spatial coverage of each event was estimated using hourly air-mass backward trajectories following the methodology described by Hussein et al. (2009). For each event, the starting time was defined as 06:00 UTC and the ending time as 12:00 UTC, based on the visualization of contour plots of particle size distribution from the NAIS (Fig. 3b). Hourly backward air-mass trajectories were traced in the upwind direction between 6:00 and 12:00 UTC, representing the possible regions where the event may have been triggered. Each trajectory represents the approximate geographical coverage of an event.

The authors come to the conclusion that entrainment and evaporation of SVOC and LVOV matter in the particles would be the main explanation of the observed NPS events. If this was the case, the observed shrinkage of the particle mean diameter from 20 nm to 5 nm (7.4. obtained from NAIS -p) would require 98% of the material in the particles to evaporate. The different volatility distribution of the particles is presented only in Figure 5f, which is somewhat difficult to understand. Also the increase of nucleation mode particle number concentration during NPS day is difficult to explain by entrainment and partitioning, unless the particles break apart physically. Please add these points in the updated discussion of the results and resulting conclusions.

Response:

The nucleation-mode particles observed during NPS events can be constrained into three physically consistent scenarios: particles were transported from nearby anthropogenic sources, formed upwind of the measurement site and subsequently advected to the site, or formed locally but failed to grow. Based on in-situ measurements, we show that local particle formation and transport from nearby anthropogenic emissions are unlikely; instead, these particles are more likely formed upwind and advected to the site.

Further NPF events are primarily attributed to the dilution of air masses. This dilution reduces particle-phase organic mass and the associated absorptive capacity of the aerosol population, thereby shifting gas-particle partitioning towards the vapor phase (Pankow, 1994;

Donahue et al., 2006). Under such conditions, semi-volatile organic compounds evaporate from nanoparticles even when gas-phase concentrations remain relatively high, as equilibrium is governed not only by vapor concentrations but also by particle-phase composition, size-dependent effects (e.g., Kelvin effect), and thermodynamic constraints (Riipinen et al., 2011; Seinfeld and Pandis, 2016)

We have revised/corrected statements in the results and discussion, abstract and conclusions sections.

Abstract: We identified three NPS events during the campaign and show that this phenomenon is not primarily driven by low concentrations of condensable vapours, their scavenging by pre-existing particles, or primary nanoparticle sources. Instead, it is associated with atmospheric dilution, as indicated by air-mass trajectory analysis. Fast-moving air masses can enhance turbulent mixing, leading to dilution of particle number concentrations and changes in particle size distributions. Together with volatility-resolved analysis, these results suggest that NPS is governed by atmospheric dilution, which reduces particle-phase organic mass and shift the gas-particle equilibrium toward evaporation, with contributions dominated by organic compounds of low and moderate volatility.

Results and discussion: The origin of the observed nanoparticles during NPS event days can be constrained into three physically consistent scenarios: the particles were either transported from nearby anthropogenic sources or formed upwind of the measurement site and subsequently advected to the site or formed locally but failed to grow. The low BC mass concentrations (Figs. 3f, 6a), together with reduced NO_x (Fig. 6d) and CO (Fig. 6e) levels, suggest that contributions from overlapping nucleation modes arising from nearby anthropogenic sources (Hakala et al., 2023; Kivekäs et al., 2016) are unlikely to explain the observed nucleation mode particles during the NPS event. Instead, these particles are more likely to be formed upwind of the site and subsequently transported to the observation location. It is therefore critical to constrain the spatial extent of over which particle formation occurs. Two approaches are commonly used to estimate this extent. The first, and more resource-intensive, approach relies on simultaneous measurements of particle size distributions at multiple stationary sites along the air-mass transport pathway. The second approach is based on hourly calculated backward air-mass trajectories. As no simultaneous measurements were available at the upwind locations of the measurement site, the spatial extent of the observed NPF and NPS events was estimated based on backward air-mass trajectory analysis, following the methodology of Hussein et al. (2009). This analysis reveals similar spatial scales for both event types (NPF and NPS; approximately 50-200 km, Fig. S8), with NPS events occurring along similar air-mass path. This suggests that particle formation occurring upwind of the measurement site on NPS event days is plausible. In our recent study, using simultaneous measurements from a low-altitude site (CAO-AMX) and a high-altitude site (Troodos, CAO-TRO), we showed that approximately half of the observed NPF events at both sites occurred concurrently along the same air-mass pathway, under the influence of an evolving planetary boundary layer height (Deot et al., 2025).

Conclusions: The similar spatial scales of these events suggest that the sub-20nm particles likely originated from particle formation occurring upwind of the measurement site. These events were further characterized by fast-moving air masses, which can enhance turbulent mixing, leading to dilution of particle concentrations and changes in particle size distributions. Such conditions reduce organic aerosol mass and shifts gas-particle equilibrium towards evaporation. Volatility-resolved analysis further indicated a dominance of organic compounds of low and moderate volatility. Although ULVOCs and ELVOCs concentrations were slightly higher during NPS events, particle formation and subsequent growth remained inhibited, supporting net evaporation and leading to rapid particle shrinkage.

Presentation

The manuscript is well structured with clear introduction, methods including instrumentation, results and discussion, and finally conclusions. Earlier work is mainly properly acknowledged and cited.

The figures have generally two issues:

1. Since there are so many simultaneous measurements of different parameters, the figures contain a lot of information. This is tackled by splitting them in several sub-figures. The result of this is, however, that the text and information in the sub-figures are too small and

difficult to read / interpret. The same issue is visible in the supplementary material. Please make these more clear

Response:

We believe that the font size used in the figures is consistent with or larger than, the main body text (Times New Roman, Font Size 10), ensuring readability, except for sub/super-scripts text. The comprehensive measurements have been systematically grouped according to aerosol evolution, meteorological conditions, and chemical characteristics to facilitate a clear and structured analysis of the observed NPS phenomenon.

2.The choise of colours in the figures is very difficult to a colour blind person (most commonly red-green). Please re-select the colours and / or line types to make them more readable.

Response:

We sincerely appreciate this suggestion. The color scheme used in the figures has been revised to adopt color-blind-friendly palettes, avoiding the most common pairs, such as red-green, red-black, and green-yellow, and by using different line styles where appropriate. Accordingly, Figures 2-5 in the main text, as well as Figs S3-S5 and S9-S10 in the Supplementary Information, have been revised.

References:
For the international networks listed on line 98 and around, it would be good to provide references, if available. Eg. for ACTRIS Laj et al., 2024, DOI: https://doi.org/10.1175/BAMS-D-23-0064.1

Response:

We thank the reviewer for pointing this out. We have cited relevant references as, "European Monitoring and Evaluation Programme (EMEP, Tørseth et al., 2012), Global Atmosphere Watch (GAW, Schultz et al., 2015), Aerosol, Clouds, and Trace Gases Research Infrastructure (ACTRIS, Laj et al., 2024), AErosol RObotic NETwork (AERONET, Holben et al., 1998), and EUMETNET Profiling Program (E-PROFILE, Illingworth et al., 2019)"

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