Review of Casquero-Vera et al. “Impact of desert dust on new particle formation events and cloud condensation nuclei budget in dust-influenced areas” by Anonymous Referee #1

We thank the reviewer for his/her valuable comments and suggestions that helped us to improve the quality of the manuscript. Our responses to the reviewer's comments are detailed below. Our answers to reviewer are shown in bold and the changes inserted in the manuscript are noted here in italic and between quotation marks. The changes in the new version of the manuscript are noted in red.

Response to referee #1:

The paper presents a multi-site analysis of the occurrence of NPF events under the presence of desert dust particles in dust-influenced areas. In the paper, authors characterize NPF events at 5 different locations highly influenced by desert dust outbreaks under dusty and non-dusty conditions by using continuous measurements of aerosol size distribution in both fine and coarse size fractions. In this study, results show that the occurrence of NPF events is highly frequent during desert dust outbreaks, showing that NPF event frequencies during dusty conditions are similar to those observed during non-dusty conditions. Furthermore, results showed that NPF events also occur during intense desert dust outbreaks at all the studied 5 sites, even at remote sites where the amount of precursor vapours is expected to be low. Furthermore, authors also found that the contribution of NPF events to cloud condensation nuclei (CCN) budget is larger during dusty conditions than during non-dusty conditions. This study is imperative to improve our understanding on the effect of desert dust outbreaks on NPF and CCN budget for better climate change prediction.

Overall, the study describes the background and introduction, and methods in a comprehensive way. Therefore, I would encourage the authors to submit a revised manuscript by addressing my specific comments below:

A point by point response is included below.

1) Please explain Figures 5 and 7 in detail, more explicitly, So far I don't understand the statement in the current manuscript "....Thus, in addition to the possible particle coating by soluble material which could increase CCN activity of desert dust particles, the formation and growth of new particles is an additional source to be taken into account. However, all this would depend on the origin of desert dust and precursor vapors...".- please be clear about what consequence is the authors referring to.

It is not clear to the authors what the reviewer refers to, but we have revised the section related with Figure 7 and the following paragraph has been modified as follows (P21 L20-P22 L6):

"While this study reveal a significant impact of class I NPF events on CCN budget during desert dust outbreaks at the studied sites, several questions remain unexplained, such as 1) how desert dust influences cloud formation?, and 2) what is the separate contribution of desert dust and NPF to the CCN budget during NPF occurring during desert dust periods?. In this sense, desert dust has been thought to uptake condensable material (such as sulphuric acid or organics) onto the surface of desert particles, depleting the reservoir of material required to create other CCN. However, we found that NPF events occur during dusty conditions, implying that NPF events contribute to CCN budgets at the studied sites even during dusty conditions. Thus, two factors could increase the CCN budget during desert dust events: 1) the possible particle coating by soluble material which could increase CCN activity of desert dust particles and 2) as shown here, the formation and growth of new particles to CCN sizes which is an additional source to be considered. However, all this would depend on the origin of desert dust and precursor vapours. Thus, to improve our understanding in the effect of desert dust outbreaks on NPF and CCN budget, further investigation accompanied by multiplatform measurement campaigns with state-of-the-art gaseous and particulate physical and chemical properties measurements is still needed."

2) In Page 6 lines 3-4: "The classification of NPF event days was done by visual inspection of the daily particle number size distribution data according to the guidelines presented by Dal Maso et al. (2005). "- what are the changes which relate to this study?

The criteria used here is the same than the one used by Dal Maso et al. (2005) for the classification on event, non-event, undefined and bad-data days. However, Dal Maso et al. (2005) classified events on class I and II events and further divided class I events into sub-classes Ia and Ib. Dal Maso et al. (2005) refers to class Ia as those events with clear with strong particle formation events and little or no pre-existing particles, making them suitable for modelling case studies and class Ib contains the rest of class I events. Our classification uses the same criteria than Dal Maso et al. (2005) but including class Ib events into the class II category (events when the NPF growth rate retrieval is not possible) and the events called by Dal Maso et al. (2005) as Ia (when the NPF growth rate retrieval is possible), are simply label in this study as class I events.

In order to clarify this statement we have modified the paragraph as follows:

"*The classification of NPF event days was done by visual inspection of the daily particle number size distribution data according to the guidelines presented by Dal Maso et al. (2005). According to this classification criteria, days are classified into four groups: NPF event (E), non-event (NE), undefined (UN) and bad-data days (BD). (1) "E" days are days during which sub-25 nm particle formation and their consequent growth are observed, (2) "NE" days are days on which neither new*

growing modes nor production of sub-25 nm particles are observed, (3) "UN" days are the days which do not fit either of the previous classes, and (4) "BD" days are the days during which data are not valid or inexistent. In addition, event days are separated into two different groups: class I and II events. Class I contains days with very clear and strong new particle formation in which it was possible to retrieve the formation and growth rate and class II includes the rest of NPF events."

3) In Page 12 lines 2-4: This complicated sentence is too long to understand.

This sentence has been removed in this version of the manuscript because it is information that has already been mentioned before (e.g., P2 L26-27).

4) What is the unit of the condensation sink (CS)?

The unit of the condensation sink (CS, CSc and CSf) is "s^{-1}" and first time we present the unit is P12 L21 and figure 3.

5) In introduction section, please be clear about the specific current situation and problems.

We have modified the introduction including the lack of knowledge on the effect of the CS (P3 L4-8) and also a discussion about why desert dust acting as CS is of special interest and the role that some desert dust chemical compounds could have on the process of NPF events (P3 L17-29):

P3 L4-8: *"However, traditionally, the effects of the morphology, physical state and chemical composition of the pre-existing particles are ignored in the calculation of CS. Overall, according to theoretical calculations, CS still too high for NPF events to occur (Du et al., 2022) and, therefore, further investigations on the effect of different vapours and pre-existing particle characteristics on the occurrence of NPF events are still needed (Tuovinen et al., 2020; 2021).*"

P3 L17-29: "*The climatic effects of desert dust and atmospheric NPF have been thought to be disconnected from each other, however, high dust loadings can affect NPF in opposing ways. Desert dust can inhibit the NPF process 1) by reducing UV radiation and thus reducing photochemical processes and 2) by increasing the scavenging rates of precursor vapours by desert dust particles and thereby supressing or reducing the new particle formation and growth rates during NPF events (de Reus et al., 2000; Ndour et al., 2009). However, desert dust can also enhance the NPF process by enhancing the formation of OH and other radicals by the presence of catalyst components in the desert dust particles, favouring oxidation reactions and therefore promoting the occurrence of NPF events during dusty conditions. In fact, several authors revealed that TiO_2 and Fe_2O (which are common components of desert dust) act as photocatalysts and under UV light could promote the heterogeneous oxidation of SO_2 and the subsequent formation of gaseous H_2SO_4, inducing NPF (e.g. Dupart et al., 2012 and references therein). These*

components, acting as catalysts, are not consumed in the photocatalytic reaction and can accelerate atmospheric photochemistry repeatedly. Furthermore, more recent laboratory study showed that the presence of TiO_2 greatly promotes NPF and can enhance the particle formation and growth rates by a factor up to 3 and 2, respectively (Zhang et al., 2023). However, clear association between desert dust loadings and the occurrence or strength of NPF has not yet been established."