Referee comments are in black. Our responses are in blue.

The authors appreciate the comments made by the three referees. These comments, especially by Referee #1 and #3, motivated us to review the entrainment and scavenging efficiency calculations in terms of both the averages and uncertainties. As a result, there are several minor updates to the numbers presented in Tables S2 and S3. However, these changes do not affect the conclusions drawn in the submitted manuscript. Further, the comments posed by all three referees have strengthened the conclusions of the paper.

Anonymous Referee #2, 27 Mar 2026

This paper describes aerosol scavenging in deep convective storms based on DC3 and SEAC4RC field measurements and the entrainment model simulations. The deep convective cloud scavenging efficiencies of sulfate, nitrate, ammonium, and organic aerosols are calculated, and physical and chemical processes affecting the scavenging efficiency analyzed. The results provide valuable information and dataset for further investigating the spatiotemporal distributions of aerosols in the upper troposphere. The paper is well written in general and can be accepted for publication in ACP subject to minor revisions.

Comments in detail

In this study, the scavenging efficiencies (SEs) of sulfate, ammonium, and nitrate aerosols are calculated based on aircraft observations combined with parcel model simulations. The results show that organic nitrate SEs (~40%) are lower than sulfate and ammonium SEs (75%), and the causes of difference are attributed to the entrainment of mid-tropospheric nitrate layers formed from lightning-produced nitrogen oxides. These results appear to be sensible/reasonable from the field observation of view. On the other hand, scavenging here should be referred to wet deposition of aerosols via nucleation, impaction and Brownian diffusion, as mentioned in this paper. This wet scavenging process is clearly defined and treated separately from the lightning production of nitrogen oxides in regional or global chemistry model. The questions are:

Thank you for providing the short summary of our findings. To clarify, the causes of differences between particulate nitrate SEs (~40%) and sulfate and ammonium SEs (75%) are likely due to lightning-produced nitrogen oxides. The entrainment of mid-tropospheric nitrate layers can explain some of the difference but not all of it.

The observational analysis focuses primarily on the nucleation scavenging since it utilizes information of air composition entering the storm near cloud base and exiting the storm near cloud top. Thus, the study is confined to processes occurring between cloud base and cloud top. Any impaction scavenging of aerosols by falling precipitation below cloud is not part of the current analysis. Wet deposition, or the removal of aerosols within precipitation to the Earth’s surface, would include scavenging occurring between the surface and cloud top. Thus, it is not quite correct to refer to scavenging, as presented in this paper, as wet deposition. A sentence has been added to the introduction (L64-67) mentioning that wet deposition is a result of many processes within the storm.

It is quite true that wet scavenging is treated separately from lightning-NO_x production in our chemistry transport models. In some models, convective transport and wet scavenging are treated separately as well. The findings from our study suggest that models should not overly isolate processes that occur within convection. We now comment about this point in the Conclusions (L666-669) of the paper.

Could the term 'scavenging efficiency' and calculation method still be used appropriately in the case that there are much more aerosols entrained from mid-troposphere than from the inflow region?

This is a good question, which depends on the context of the topic or application. If one is focused on how much of the aerosol is removed from the gas phase into the cloud particles, then scavenging would be focused on that one process. However, if the topic is how good is the representation of aerosol scavenging in convection in a regional or global models, then one should consider the collection of processes (vertical transport, entrainment, scavenging, gas and aqueous chemistry, and lightning-NO_x production) together as scavenging. Isolating one or more of these processes can be achieved (e.g., the model's capability of representing convective transport can be evaluated with insoluble, passive trace gases). Yet, the evaluation of a model is often performed by comparing the simulated aerosol concentrations to measurements, which are a result from the combination of processes occurring within the convection. We now comment about this point in the Conclusions (L666-669) of the paper.

Should nitrate have a same SE level as sulfate and ammonium if there were no nitrate mid-troposphere layer or lightning nitrogen oxide source in the model simulation?

This question can be answered by estimating the nitrate aerosol SEs from storms that do not have a mid-troposphere layer or lightning-NO_x source. We report pNO_3 SEs for five storms: 29 May 2012, 6 June 2012, 16 June 2012, 2 September 2013 airmass, and the land convection on 18 September 2013. In the table below we list only the averages of the pNO_3, SO_4^{2-}, and NH_4^+ SEs for those five storms and note whether there was a mid-troposphere pNO_3 layer and the NO_x mixing ratio in the outflow region. To answer the reviewer's question, a storm with low NO_x mixing ratios in the outflow region and no mid-tropospheric pNO_3 layer would be needed. Two SEAC^{4}RS storms (2 September 2013 airmass and 18 September 2013 land convection) fulfill these two criteria. For the 18 September 2013 storm, the measured outflow pNO_3 concentration was below the detection limit indicating 100% scavenging. However, the 2 September 2013 storm has a moderate pNO_3 scavenging efficiency of 43%, suggesting other factors may play a role and noting that the outflow pNO_3 concentrations and NO_x mixing ratios have a high variability compared to their average outflow values. A high pNO_3 scavenging efficiency is also seen in the 16 June 2012 case even though the outflow NO_x mixing ratios are > 1 ppbv. We now note this finding in section 7.3 (L509-516) that discusses the scavenging of nitrate aerosols.

Storm	pNO_3^- SE (%)	SO_4^{2-} SE (%)	NH_4^- SE (%)	Outflow NO_x (pptv)	Mid-troposphere pNO_3 layer
29 May 2012	40.5	86.8	81.3	1366 +/- 2159	No
6 June 2012	41.9	89.6	86.0	660 +/- 541	Yes
16 June 2012	82.8	90.7	87.6	2124 +/- 916	No
2 September 2013	42.9	95.0	100	146 +/- 230	No
18 September 2013	100	90.7	100	321 +/- 60	No

It might not realistic to address these issues by performing additional modeling work. But adding some discussions in the conclusions might be helpful for guiding future modeling research.

We have added some discussions to the conclusions section of the paper.