Review Report on “Aitken mode particles as CCN in aerosol- and updraft-sensitive regimes of cloud droplet formation” by Pöhlker et al

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**General Comments:**

It is widely thought that aerosols in accumulation mode contribute to the activation processes, and aerosols in Aitken mode are usually ignored in most studies. This manuscript demonstrates the role of aerosols in Aitken mode by adiabatic cloud parcel model. They found that the activation of Aitken mode plays roles in the ACI, especially in the dependence of Nd to hygroscopicity $\xi(\kappa)$. They also show the regime patter of Nd and $\xi(\kappa)$ in many sensitivity studies with monomodal and bimodal. Overall, this manuscript adds value in the community that it provides a theoretical analysis of the roles of Aitken model aerosols in the activation processes, which is necessary but hasn't been done before. However, some details need to be revised or clarified. I recommend a minor revision.

**Specific comments:**

1. It is not surprising that at higher w and higher $\kappa$ that Aitken mode is more important, because higher values of either one or both favor the activation of smaller particles. It is good that authors include threshold to tell if Aitken mode is important ($F_{Ait}$>0.05). It is better to also show which part of Aitken mode is important, because $F_{Ait}$ is smaller than $F_{accu}$ in the simulations shown in the manuscript.
2. Fixed values for droplet criterion lead to a problem that those particles will grow to the cloud droplet at high altitudes but are not taken into account as droplets close to cloud base, because the time that particles expose to the supersaturation is not long enough. That is why $\xi(\kappa)$ increases (Figure 2f) and coincides with the orange box in Figure S4. In other saying, the increasing $\xi(\kappa)$ above $S_{max}$ might only be a manifestation from the assumption of fixed values for droplet criterion. I suggest more discussions on that with more similar figures as Figure 2e-f, using the droplet criterion in Reutter et al 2009.
3. Figure 3 is presented at about 20m above $S_{max}$, where $\xi(\kappa)$ has not reached to steady state based on Figure 2f. When the parcel further goes higher, those cases with high $\kappa$

will correspond to the higher $\xi(\kappa)$. I guess that at 40m, the minimum of $\xi(\kappa)$ in the w-$\kappa$ will move to the smaller w and $\kappa$ side. Those differences might not exist if not using the fixed criterion for $N_d$. I suggest two more figures 1) a similar figure as Figure 3 except at 40m with same fixed size as criterion for $N_d$, and 2) a similar figure as Figure 3 but using the same criterion as Reutter et al 2009.

4. Figure S3 shows the vertical profiles of supersaturation and is only mentioned briefly on Line 144. Activated of Aitken mode aerosols depends on the supersaturation and also feedbacks to the supersaturation through the second term in Equation E2. In Fugure S3, it is interesting to see at 1m/s, adding Aitken mode suppresses the supersaturation and decreases the cloud base height, while at 0.2 m/s, adding Aitken mode enhances the supersaturation and increases the cloud base height. More discussion on that will be a good addition to this manuscript.
5. Line 209-211, with different combination of w and $\kappa$, same $D_{min}$ and $\xi(\kappa)$ can be reached, as where the lines with different color cross in figure 3b and 3c. How about those points with same $D_{min}$ but different $\xi(\kappa)$? In other saying, with a same aerosol size distribution and same $D_{min}$, why $\xi(\kappa)$ are different?
6. In Figure S6b, the minimum points of the green and cyan lines are not at the same size of Hoppel minimum diameter. Why is that?
7. Line 234, it is easy to understand that high $\xi(N_a)$ in aerosol-limited regime, but why the $\xi(N_a)$ is also large in the w-limited regime? In w-limited regime, $N_d$ is supposed to be dependent on w and much less dependent with $N_a$, thus $\xi(N_a)$ should be any values close to 0. Also, I don't understand why there is a minimum in Figure 4b.
8. First of all, the color scheme in Figure 4c is very hard to read. Does the more transparent color scheme represent the total $N_d$ or only the $N_d$ corresponding to aerosols in accumulation mode? Secondly, the authors stated that the differences between simulation ASD I and ASD III represent the effects of Aitken mode. However, the total aerosol number concentration is different in these two simulations. In my opinion, $N_a$-limited regime corresponds to the scenario that $N_a$ is small but doubling $N_a$ itself contributes to the vanishing of aerosol-limited regime. In this case, the differences

between ASD I and ASD III include both change in total Na and the number of modal. I have same comments for Line 258-259. In other saying, the vanishing of aerosol-limited regime might not be a feature for monomodal v.s. bimodal. It might be a feature due to the increasing $N_a$.

9. Those contour figures showing the dependence of $\xi(\kappa)$ on w and $\kappa$ are very noisy, especially V.c in Figure 5 (right bottom one). There is no way to tell the trends in V.c in Figure 5. My experience tells me that increasing the number of particle bins (i.e., 545 particle size classes mentioned in section 2.2.1) can improve the noisy problems. Hope this also helps to improve the quality of that figure. Moreover, in Figure 2f, it is hard to tell the reverse relationships between $\xi(\kappa)$ and $\kappa$ at high altitudes. Perhaps less lines can show the reverse better.
10. Line 305 "Nd is highly sensitive to $\kappa$ and w, and less to $N_{a,Ait}$". The activation fraction in Aitken mode is much smaller than that in the accumulation mode. That might be caused by the small lower size limit of Aitken mode in those simulations. What will happen if the simulation only includes the relative larger particles in Aitken mode so that the activation fraction in Aitken mode is comparable to that in accumulation mode? Na might be important in that way. Section 3.3.2 shows the impacts of Dg on the $\xi(\kappa)$. I think it is better to have more discussion about relative importance of $N_a$, w and $\kappa$ when $D_{g,Ait}$ is larger. This is also related to my first comment that it will be useful to provide the information that which part of Aitken mode is more important for ACI.

**Minor comments:**

1. the section 3.1. presents in the way that w and $\kappa$ are equally important, it is better to move at least one between Figure S1 and S2 (better both) to the main text to show the dependence on w.
2. Line 10, add a comma after $N_d$.
3. Line 175, change "S3" to "S4".
4. Line 257, impacts of $D_g$ has not been shown here, so it is early to include it in the summary here.