First of all, we would like appreciate the reviewer's comments and suggestions. In response to the reviewer comments, we have made relevant revisions in the manuscript. Listed below are our answers and the changes made to the manuscript according to the questions and suggestions given by the reviewers. Each comment of the reviewer is listed (black) and followed by our responses (blue).

Interactive comment on "Impact of solar radiation on aerosol-cloud interactions in thin stratocumulus clouds" by S. S. Lee and J. E. Penner

Anonymous Referee #2

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This study examines the effect of changes in aerosol concentration and solar radiation on thin, marine Stratocumulus with LWP of _50 g m-2 or less, i.e. non-precipitating marine Sc. The authors employ a liquid water budget analysis to demonstrate that aerosol effects on condensation in thin, non-precipitating marine Sc are more important than aerosol effects on precipitating processes in determining the overall cloud response. The overall results compare well with other studies on a similar subject, e.g Wang et. al, 2003; Bretherton et al, 2007; Hill et al, 2008, 2009. While the budget analysis demonstrates that condensation is more important than accretion or autoconversion, this paper fails to present the underlying mechanisms for the change in LWP with changes in aerosol. Previous work by a number of researchers (see below) has proposed mechanisms by which aerosol induced changes in condensation/evaporation influence cloud dynamics of non-precipitating clouds, which in turn leads to changes in LWP; however, none of this work is discussed or tested. Thus, while the results are comparable to previous work, such results have not been put into context, so it is hard to understand how original the conclusions are. Furthermore, I question the author's rejection of the role of sedimentation in the LWP response to aerosol. This rejection seems to stem from overlooking some the aerosol-cloud-dynamic interactions discussed in previous work, interactions that would not be born out of their budget analysis.

To support our ideas about the feedbacks among CDNC (or N_d), supesaturation, and dynamics in cases with the surface precipitation and the interplay of these feedbacks with those between rain evaporation and cloud-base instability in cases with no surface precipitation, which controls the LWP response to aerosols in this study, additional simulations are performed and their description and implications are given in Section 5.4 in the new manuscript as follows (between dashed lines):

(LL565-632 in p19-22)

A pair of additional simulations, which is composed of the high- and low-aerosol runs, in each of the four cases in this study is performed. This pair of simulations adopts the identical N_d only for condensation in each of the four cases; N_d in Eq. (3) is fixed at a constant value and forced to be the same for the high- and low-aerosol runs, though predicted N_d is allowed to be used in the other processes. The budget numbers of Eq. (2) for these additional simulations are shown in Table 3. This pair of simulations is referred to as the high-aerosol run (N_d-high fixed) and low-aerosol run (N_d-high fixed) in each of the four cases. The high-aerosol run (N_d-high fixed) and low-aerosol run (N_d-high fixed) in each of SW-M1.5, CONTROL, SW-D2, and SW-D5 adopt an averaged N_d in the high-aerosol run in each of SW-M1.5, CONTROL, SW-D2, and SW-D5 as a fixed value only for condensation as described in Table 1.

The LWPs in the low-aerosol runs (N_d-high fixed) increase significantly as compared to LWPs in the low-aerosol runs, resulting in negligible differences in LWP between the high-aerosol run (N_d-high fixed) and low-aerosol run (N_d-high fixed) in each of SW-D2 and SW-D5. This is mainly due to larger N_d in the low-aerosol runs (N_d-high fixed) than average N_d in the low-aerosol runs, leading to increased condensation as compared to that in the low-aerosol runs (Table 3). These additional simulations indicate that the LWP responses to aerosols can be nearly the same for the high- and low-aerosol runs only by making N_d for condensation identical. This demonstrates the most crucial role of N_d impacts on condensation in the LWP responses to aerosols in SW-D2 and SW-D5. This also demonstrates that the impacts of aerosols and thus N_d on the other processes such as the sedimentation of cloud liquid, the conversion of cloud liquid to rain, thus, the sedimentation and evaporation of rain do not play an important role in the LWP responses in thin clouds with the surface precipitation here.

Time- and domain-averaged LWPs in the high-aerosol run (N_d-high fixed) and low-aerosol run (N_d-high fixed) are 10.8 and 14.6 g m^{-2}, respectively, in SW-M1.5. In CONTROL, the LWPs are 13.0 and 19.5 g m^{-2} in the high-aerosol run (N_d-high fixed) and low-aerosol run (N_d-high fixed), respectively (Table 3). These additional simulations for SW-M1.5 and CONTROL with the absence of the surface precipitation show a larger increase in LWP in the low-aerosol run (N_d-high fixed) than that in the low-aerosol run. This is due to the near absence of increased interactions between N_d and supersaturation in the high-aerosol run (N_d-high fixed) as compared to those in the low-aerosol run (N_d-high fixed). This is caused by the increase in the intensity of these interactions in the low-aerosol run (N_d-high fixed) as compared to that in the low-aerosol run. Due to the increase in N_d in the low-aerosol run (N_d-high fixed) as compared to N_d in the low-aerosol run, the intensity of the interactions increases in the low-aerosol run (N_d-high fixed) as compared to that in the low-aerosol run. This increase in the intensity of the interactions acts to increase condensation together with the increased cloud-base instability in the low-aerosol run (N_d-high fixed), leading to the larger increase in LWP in the low-aerosol run (N_d-high fixed) than in the low-aerosol run.

The high- and low-aerosol runs are repeated for all of the four cases again by turning off sedimentation and evaporation of rain and sedimentation of droplets to investigate the role of rain evaporation and hydrometeor sedimentation in thin clouds and their responses to aerosols and referred to as the high-aerosol run (sed-off) and the low-aerosol run (sed-off). As shown in Table 4, the qualitative nature of the results described for the high- and low-aerosol runs does not change with whether rain evaporation and hydrometeor sedimentation operate in SW-D2 and SW-D5 with the surface precipitation. However, condensation and LWP increase in the high-aerosol run (sed-off) in SW-M1.5 and COTROL (with no surface precipitation) due to the absence of cloud-base evaporation and its effect on the cloud-system instability, contrary to their decrease in the high-aerosol run.

Table 5 shows the budget numbers for repeated simulations for the high- and low-aerosol runs both with the fixed N_d (adopting an averaged N_d in the high-aerosol run) only for condensation and with rain evaporation and hydrometeor sedimentation turned off. This pair of simulations is referred to as the high-aerosol run (N_d-high fixed and sed-off) and low-aerosol run (N_d-high fixed and sed-off) in each of the four cases. Over all of the four cases, the LWP difference between the high- and low-aerosol runs is negligible as compared to that between the high- and low-aerosol runs. This demonstrates that interplay between interactions among N_d, supersaturation, and dynamics and those between rain evaporation and cloud-base instability predominantly determines the LWP response to aerosols in SW-M1.5 and CONTROL. That both the pair of the high- and low-aerosol runs (N_d-high fixed) and the pair of high- and low-aerosol runs (N_d-high fixed and sed-off) show negligible differences in LWP between the high- and low-aerosol cases demonstrates that interactions among N_d, supersaturation, and dynamics play the most important role in the determination of the LWP response to aerosols in SW-D2 and SW-D5; whether rain evaporation and hydrometeor sedimentation are included does not affect the negligible LWP differences in these two pairs of simulations in each of SW-D2 and SW-D5.

In SW-D2 and SW-D5, stronger interactions among N_d, supersaturation, and condensation (leading to more evaporation) induce a larger entrainment at high aerosol than at low aerosol; entrainment rate is calculated as the growth rate of the inversion layer. Simulations with identical CDNC for condensation for each of these two cases have nearly identical entrainment rates due to nearly identical interactions among CDNC, supersaturation, and dynamics. Hence, variation in entrainment is controlled by that in interactions among CDNC, supersaturation, and dynamics with varying aerosols and the condensation increase (due to increased interactions among CDNC, supersaturation, and dynamics) is large enough to offset the effect of increasing entrainment, leading to larger LWP at high aerosol in SW-D2 and SW-D5. In SW-M1.5 and CONTROL with no surface precipitation, both interactions among CDNC, supersaturation, and dynamics and those between cloud-base rain evaporation and instability control entrainment (by affecting condensation and cloud-liquid evaporation). Simulations with identical CDNC and with rain evaporation and hydrometeor sedimentation turned off for each of these two cases show nearly identical entrainment, indicating the feedbacks between cloud-base instability and dynamics and those between CDNC, supersaturation and dynamics play an important role in the entrainment variation with varying aerosols. Condensation increase (due to increased interactions between rain evaporation and cloud-base instability) is large enough to offset the effect of increasing entrainment, leading to larger LWP in the low-aerosol run in SW-M1.5 and CONTROL.

The budget analysis in this study was carried out to find out which microphysical terms dominate in determining the liquid-water content (LWC). Although the budget analysis does not enable us to find the cause of the higher LWP (the vertical integration of LWC (only including cloud liquid, excluding rain)), it is at least able to find the dominant microphysical terms determining the rate of change of the LWC and thereby the LWP variation due to aerosols. Note that there are only four terms controlling LWC and LWP, which are condensation, evaporation, autoconversion, and accretion. The LWC sink in Albrecht's argument is about the depletion of cloud-liquid mass via autoconversion and accretion (forming rain). Albrecht argued that decreasing autoconversion and accretion with increasing aerosols led to increasing LWC and LWP.

Since we are interested in explaining the variation in "time- and domain-averaged LWP" with varying aerosols, all of the cumulative microphysical terms in the LWC tendency, which are averaged over the domain, are obtained. The budget analysis shown in Table 2 demonstrates that variations in cumulative condensation and evaporation are the main controls among the four microphysical terms determining the variation in the time- and domain-averaged LWP and that the cumulative conversion of cloud liquid to rain by autoconversion and the accretion of cloud liquid by rain play a minor role in controlling the variations in the time- and domain-averaged LWP as compared to condensation and evaporation of cloud liquid. Hence, Albrecht's autoconversion and accretion do not play an important role in the response of the time- and domain-averaged LWP to aerosol changes in simulations here.

Cloud liquid formed by condensation eventually disappears via evaporation and very small portion of cloud liquid converts to rain via autoconversion and accretion before its disappearance in this study. This indicates that (cumulative) condensation controls (cumulative) evaporation by determining the amount of source (i.e., cloud liquid) of evaporation; the role of autoconversion, accretion, and sedimentation in the determination of the source is not significant. Larger (smaller) cumulative condensation induces larger (smaller) cloud liquid, contributing to larger (smaller) time- and domain-averaged LWP. Larger (smaller) cloud liquid eventually disappears and this disappearance should involve larger (smaller) cumulative evaporation for larger (smaller) cloud liquid (produced by larger (smaller) condensation).

Differences in evaporation between the high- and low-aerosol runs decrease substantially as does those in condensation when CDNC is fixed for the condensation term only; experiments with the fixed CDNC are described in our responses to one of the comments above. Differences in evaporation and condensation are only ~ 25 (17) and ~ 28 (17) % of those in the standard high- and low-aerosol runs where the CDNC is predicted for all processes including condensation in SW-D2 (SW-D5). In the standard high- and low-aerosol runs where the CDNC is predicted for all processes including condensation, larger cloud-liquid mass eventually contributes to larger evaporation when the cloud liquid is detrained from the updrafts into the sub-saturated areas (as can be seen from the budget analysis using cumulative values at the end of time integration). When CDNC is fixed for condensation, differences in the cloud-liquid mass decrease due to the reduced differences in the production of cloud liquid by condensation between the high- and low-aerosol runs in SW-D2 and SW-D5; in CONTROL and SW-M1.5, when both CDNC is fixed for condensation and rain evaporation and hydrometeor sedimentation are turned off, differences in the cloud-liquid mass become negligible due to the reduced differences in the production of cloud liquid by condensation between the high- and low-aerosol runs. This leads to reduced differences in the detrained mass of cloud-liquid into the sub-saturated areas and thereby to reduced differences in evaporation of cloud liquid. This confirms the above argument that cumulative condensation not only controls the time- and domain-averaged cloud-liquid mass variations (and therefore the time- and domain-averaged LWP variations) but also controls the variations in cumulative evaporation due to aerosols.

In summary, the variation in the time- and domain-averaged LWP is mostly controlled by the variations in the cumulative condensation and the cumulative evaporation of cloud liquid and the variation in the cumulative evaporation of cloud liquid are controlled by the variation in the cumulative condensation which provides the source for the evaporation of cloud liquid; here, we want to stress that the time series of the domain-averaged differences in condensation and evaporation between the high- and low-aerosol runs showed much larger values than those from autoconversion and the collection of cloud liquid by rain throughout simulation periods, indicating that the cumulative values of these processes at the end of time integration can represent situations during the time integration reasonably well. From the budget analysis (using the cumulative values), we can see condensation and evaporation are two major terms controlling the cloud-liquid mass and autoconversion and accretion play an insignificant role in the determination of the cloud-liquid mass. It is the cumulative condensation (evaporation) which increases (decreases) the time- and domain-averaged LWP and our additional simulations with the fixed CDNC (and no hydrometeor sedimentation and rain evaporation for cases with no surface precipitation) demonstrate that the cumulative evaporation is controlled by the cumulative condensation. Hence, we can say that the LWP which is averaged over time and domain is determined by the cumulative condensation which eventually affects the cumulative evaporation and, thus, we can only use the cumulative condensation to explain the LWP and its variation due to aerosol changes or the cumulative evaporation and its variation due to aerosol changes. It is also possible to say that evaporation plays much more important roles in the response of the LWP to aerosol changes than the conversion. However, increasing evaporation with the variation in aerosols is not able to explain increasing LWP with the aerosol variation. The increase in the cumulative condensation best explains the increase in the time- and domain-averaged LWP with the negligible conversion in this study. This is why this study performed comparison between condensation and conversion but not between evaporation and conversion. Also, by showing much larger condensation and its variation with aerosols than the conversion and its variation, we can simultaneously explain larger evaporation and its variation with aerosols than the conversion and its variation due to the connections between condensation and evaporation as explained above. Hence, we analyzed the terms determining the condensation rate in section 5.3 and found that the CDNC and supersaturation variations dominate the condensation variation. Supersaturation represents the dynamical and thermodynamical impacts (e.g., moisture fluxes and entrainment) on condensation, since it is affected by the updraft intensity, temperature and moisture in air parcels. The analysis in section 5.3 showed that the impact of changes in microphysical factors (i.e.,CDNC) on condensation can offset that in dynamical and thermodynamical factors, represented by supersaturation, by changing the surface areas of droplets. Here, we want to stress that it is obvious that condensation is controlled by variables in Eq. (3) and, as expected, the ventilation coefficient and the saturation water vapor mixing ratio showed negligible differences between the high- and low-aerosol runs as compared to those in supersaturation and CDNC. Thus, the supersaturation and CDNC changes explain the cause of the larger condensation resulting in larger LWC and LWP at high aerosol in SW-D2 and SW-D5 as shown in the budget analysis in section 5.2; as explained in our response to one of comments above, the aerosol-induced changes in CDNC control the change in interactions between CDNC and supersaturation and their effect on the aerosol-induced change in condensation based on additional simulations with CDNC fixed. The CDNC and supersaturation effects on condensation offset each other as explained in the text and the CDNC effects are larger than the supersaturation effects, leading to more condensation and LWC (and thus LWP) at high aerosol in SW-D2 and SW-D5. As explained in the text, in SW-M1.5 and CONTROL, the interactions between cloud-base rain evaporation and cloud-base instability interplay with those between CDNC and supersaturation due to the absence of the surface precipitation, resulting in larger LWP at low aerosol in SW-M1.5 and CONTROL.

To some extent the authors do demonstrate the importance of solar radiation; however, once again the authors fail to reference or compare their results with previous work on the same subject.

The comparison with previous work is done and described as follows in the text:

(LL682-729 in p23-25)

Previous studies have shown that the evaporation-entrainment effect (Wang et al, 2003; Hill et al., 2008 and 2009) and the sedimentation-entrainment effect (Ackerman et al., 2004; Bretherton et al., 2007; Sandu et al., 2008; Hill et al., 2009) determine the LWP responses to aerosols. These studies found that increasing evaporation efficiency (inducing the evaporation-entrainment effect) and source of evaporation due to decreasing sedimentation (inducing the sedimentation-entrainment effect) with increasing aerosols led to a decreasing LWP. This decrease in LWP with increasing aerosols was simulated in both drizzling (Ackerman et al., 2004; Sandu et al., 2008) and non-drizzling stratocumulus clouds (Wang et al, 2003; Bretherton et al., 2007; Hill et al., 2008 and 2009). Ackerman et al. (2004) found that LWP decreased with increasing aerosols due to increasing entrainment only when the surface precipitation rate was smaller than 0.1 mm day^{-1}. With the surface precipitation larger than 0.1 mm day^{-1}, less hydrometeor removed from clouds as precipitation increased LWP with increasing aerosols, which is consistent with the effect of aerosols on LWP proposed by Albrecht (1989). Contrary to Ackerman et al. (2004), this study showed that LWP increased at high aerosol due to intensified interactions among N_d, supersaturaton, and updrafts in cases with the surface precipitation less than 0.1 mm day^{-1}. In this study, the averaged LWP and maximum LWP during simulations were smaller than 50 g m^{-2}. However, in Ackerman et al. (2004), the averaged LWP was larger than 70 g m^{-2}. Results here are also contrary to Sandu et al. (2008) who simulated clouds (with the surface precipitation) with averaged LWP > 50 g m^{-2} and with the maximum LWP of ~ 150 g m^{-2}. Khairoutdinov and Kogan (2000) indicated that the sensitivity of the conversion of cloud liquid to rain to varying N_d was weaker at low LWP than at high LWP. This implies that the sensitivity of the growth of droplets through collisions with other particles (controlling the conversion of cloud liquid to rain) and thus the sensitivity of sedimentation (controlled by the sensitivity of particle growth) to aerosol changes (leading to N_d changes) is weaker at low LWP. The variation of the conversion of cloud droplets to rain with varying aerosols was not large enough to make a significant difference in the sedimentation of cloud particles among simulations with low LWP here, as implied by the study of Khairoutdinov and Kogan (2000). This led to a negligible role of sedimentation in the LWP response to aerosols, which in turn led to the negligible role of entrainment (and thus the negligible role of the sedimentation-entrainment effect) in the LWP response to aerosols. Also, the increase in the evaporation efficiency was not large enough to make a significant difference in entrainment between the high- and low-aerosol runs in the thin clouds simulated here. This led to the negligible role of the evaporation-entrainment effect in the LWP response to aerosols; Lee and Penner (2009) showed that evaporation difference caused by the aerosol-induced difference in evaporation efficiency in thin clouds with LWP < 50 g m^{-2} was not as large as in relatively thick clouds with LWP > 50 g m^{-2}. Instead, the role of interactions among N_d, supersaturation and updrafts in the LWP response to aerosols became more important than that of entrainment in the drizzling clouds. In non-drizzling thin clouds with LWP < 50 g m^{-2} (in SW-M1.5 and CONTROL), the role of sedimentation, evaporation efficiency and thus entrainment in the LWP response to aerosols was also negligible. Instead, the LWP response in SW-M1.5 and CONTROL was determined by interactions among N_d, supersaturation and updrafts interplaying with those between rain evaporation and cloud-base instability due to rain evaporation which did not stabilize the whole MBL. This is contrary to relatively thick non-drizzling clouds simulated in Wang et al. (2003), Bretherton et al. (2007), Hill et al. (2008 and 2009) where entrainment played a major role in the LWP response to aerosols.

Finally, other than the inclusion of solar radiation lot of this work does not seem to be particularly new as much of what is stated in this paper has been stated by the same authors in Lee et al (2009), hence the originality of this paper is questionable.

In this study, our aim is to examine the effect of the intensity of solar radiation on aerosol-cloud interactions in “thin” stratocumulus clouds. Hence, we adopted the analysis method for “thin” stratocumulus clouds from Lee et al. (2009). Although the method in this study is adopted from Lee et al. (2009), it proves to be effective in understanding how solar radiation affects the aerosol-induced changes in cloud-liquid budget; the cloud-liquid budget can give us an insight not only into how aerosols affect the LWP but also into how the effect of aerosols on LWP varies with the intensity of solar radiation.

Despite similarity in discussions in 5.2 and 5.3 in this study to those in Lee et al. (2009), discussions in 5.2 and 5.3 are not only effective in explaining the effect of solar radiation on aerosol-cloud interactions in thin clouds but also necessary to lead to conclusions in this study. Hence, we put sections 5.3. and 5.3 in the new manuscript as well. However, similar expressions as compared to those in Lee et al. (2009) are re-written; however, the text describing Eq. (1)-(4) does not change much, since the description is mainly about their mathematical expressions.

We believe that using a similar analysis method does not mean that this study duplicated the study of Lee et al. (2009), since Lee et al. (2009) aims to understand the mechanism of aerosol-cloud interactions in thin clouds (per se) whereas this study aims to examine the dependence of these interactions on the intensity of the incident solar radiation. With varying incident solar radiation, the mechanisms controlling aerosol-cloud interactions and their effect on the LWP response to aerosols vary. This study showed that the intensity of the incident solar radiation could determine the presence of the surface precipitation, which in turn determines mechanisms for the LWP response to aerosols as described in the above response. The intensity of the incident solar radiation also affects how those mechanisms change for either cases with the surface precipitation or those with no surface precipitation. Those mechanisms are more effective in the increasing LWP with increasing aerosols in SW-D5 with higher LWP from less solar radiation causing less decoupling than in SW-D2 between cases with the surface precipitation. Between the cases with no surface precipitation, the effect of mechanisms associated with the cloud-base instability on the increasing LWP at low aerosol is stronger with higher LWP due to less decoupling (causing more conversion of cloud liquid to rain and thus rain evaporation around cloud base) from weaker incident solar radiation in CONTROL than in SW-M1.5.

For these reasons, I feel this paper should be rejected in its present form. Having said this, I feel that the topic is important and will be of interest to the community. From the description of the simulations, many of the issues that have not been tackled in this draft can be addressed with the present simulations and some extra tests. Hence, I feel the authors think about addressing the topics below and re-submitting.

Major Comments

1) This paper discusses thin marine Sc yet throughout the authors barely discuss cloud top entrainment rate, cloud top longwave cooling, cloud top evaporative cooling, which have been shown to be important processes in the evolution and diurnal variation of marine Sc. Figure 3 shows that the polluted cloud top height tends to rise in altitude earlier than the clean cloud. This indicates that there is a more efficient entrainment rate, but this is not discussed.

As discussed in our responses above, additional simulations with the CDNC fixed for condensation and with sedimentation and evaporation of rain and sedimentation of droplets turned off demonstrate that condensation (controlled by interactions among CDNC, supersaturation and dynamics (and those between rain evaporation and cloud-base instability for cases with no surface precipitation)) plays most important roles in the effect of aerosols on evaporation, entrainment and the time- and domain-averaged LWP in each of the four cases.

Simulations with identical CDNC for condensation for each of two cases with surface precipitation have nearly identical entrainment rates, cloud-top longwave and evaporative cooling due to nearly identical interactions among CDNC, supersaturation, and dynamics. Hence, as discussed in our first response above, variation in entrainment (and cloud-top cooling) is controlled by that in interactions among CDNC, supersaturation, and dynamics with varying aerosols. In SW-M1.5 and CONTROL with no surface precipitation, both interactions among CDNC, supersaturation, and dynamics and those between cloud-base rain evaporation and instability control entrainment (by affecting condensation and cloud-liquid evaporation) and cloud-top cooling.

I except that the paper is about the influence of solar radiation on aerosol-cloud interactions, with a particularly focus on an aerosol-condensation effect; however, the authors have to show how these processes inter-relate with other processes that have been demonstrated to be important in marine Sc by numerous observational, theoretical and modelling studies, including GCSS intercomparisons. By ignoring such processes there is no way to tell how important the proposed mechanisms are relative to some of the driving forces of marine Sc.

As shown in the additional experiments with the CDNC fixed, the difference in LWP is controlled by interactions among CDNC, supersaturation, and dynamics for cases with the surface precipitation; when CDNC is fixed for condensation, the difference in LWP between the high- and low-aerosol runs becomes negligible for cases with the surface precipitation. But due to more vapor transportation with less decoupling, SW-D5 shows larger LWP in both the high- and low-aerosol runs than SW-D2.

For the cases with no surface precipitation, the additional experiments with no rain evaporation and sedimentation and droplet sedimentation showed that the high-aerosol run had higher LWP due to the absence of rain evaporation around cloud base. When the CDNC is fixed and rain sedimentation and evaporation and droplet sedimentation are deactivated for cases with no surface precipitation, the difference in LWP between the high- and low-aerosol runs nearly disappears. But SW-M1.5 shows smallest LWP due to strongest decoupling among cases and CONTROL shows the second smallest LWP due to the second strongest decoupling in these additional simulations with CDNC fixed and no rain sedimentation and evaporation and droplet sedimentation.

In summary, the level of incident solar radiation determines the level of LWP and the presence of the surface precipitation. This affects mechanisms which play an important role in the response of LWP to aerosols in each of cases. In the cases with the surface precipitation, above-described additional simulations demonstrate that the interactions among CDNC, supersaturation, and dynamics play the most important role in the LWP variation with varying aerosols; the effect of these interactions on the LWP response to aerosols is stronger with higher LWP in SW-D5 due to less decoupling from weaker incident solar radiation than in SW-D2. In the cases with no surface precipitation, these interactions interplay with interactions between rain evaporation and cloud-base instability for the determination of the LWP variation; the effect of interactions between rain evaporation and cloud-base instability on the increasing LWP at low aerosol is stronger with higher LWP due to less decoupling (causing more conversion of cloud liquid to rain and thus rain evaporation around cloud base) from weaker incident solar radiation in CONTROL than in SW-M1.5.

2) I have serious doubts about section 5.2 and 5.3 for 2 reasons

- I feel this is a lifted from the Lee et al, 2009 but not referenced, so such discussion is not original

Lee et al. (2009) is referenced as follows:

(LL288-289 in p10)
following the budget-analysis method in Lee et al. (2009).

(LL340 in p12)
This follows the methodology adopted in Lee et al. (2009).

- I think there are underlying flaws in the author's conceptual model.

In Figure 4 the Control run clearly shows that the LWP is much less in the high aerosol case yet this change is not really explained. Hill et al, 2008, showed a similar response in a diurnally varying non-precipitating marine Sc. They argued this response was due to an evaporation-entrainment effect. Bretherton et al (2007) and Sandu et al (2008) showed a similar decrease in LWP and argued this resulted from a sedimentation-entrainment effect. Hill et al (2009) showed that both these processes play a role in reducing LWP in nocturnal marine Sc. Are these processes occurring in the simulations presented here? If not what is happening in the CONTROL run? It is important to establish this before sensitivity studies are used to justify a hypothesis.

As mentioned in our responses above, in CONTROL with no surface precipitation, both interactions among CDNC, supersaturation, and dynamics and those between cloud-base rain evaporation and instability control entrainment (by affecting condensation and cloud-liquid evaporation) and cloud-top cooling; the set of simulations for CONTROL with the fixed CDNC and no sedimentation of droplets and rain and no rain evaporation shows nearly no difference in condensation, evaporation, the entrainment rate and LWP between the high- and low-aerosol runs, demonstrating these interactions control the response of LWP and entrainment rate to aerosols in CONTROL.

As explained in our response to a comment above, when simulations in CONTROL are repeated with the sedimentation and evaporation of rain and droplet sedimentation turned off, the high-aerosol run (sed-off) showed the larger time- and domain-averaged LWP and entrainment rate than the low-aerosol run (sed-off), contrary to the smaller LWP and entrainment in the standard high-aerosol run than that in the standard low-aerosol run. This is due to the absence of cloud-base evaporation and its effect on the cloud-system instability. This indicates that the entrainment rate increases with increasing condensation (leading to increasing evaporation). The larger condensation from the larger cloud-base instability in CONTROL leads to larger evaporation and thus entrainment in the low-aerosol run than in the high-aerosol run. The effect of increased condensation on LWP outweighs that of increased entrainment, leading to larger LWP in the low-aerosol run than in the high-aerosol run. However, if environmental conditions are different than adopted here, condensation and thus LWP can decrease with decreased aerosols in CONTROL, in other words, the effect of entrainment on the LWP can outweigh those of condensation on LWP. For example, in case the cloud-top humidity is extremely dry, entrainment increases with decreased aerosols in CONTROL can lead to decreasing condensation and LWP (based on Ackerman et al. (2004)). However, the cloud-top humidity is high enough to lead to the increased condensation and LWP with decreased aerosols in CONTROL.

From the later results (Figure 8 and description of SW-M1.5), I think the authors believe that the reduction in the LWP with increasing aerosol is the result of less cumulative condensation leading lower LWP. I am struggling with this explanation. I except that increasing CDNC leads to an increase in competition for water vapour, an increase in the condensation rate and stronger updrafts; however, this is associated with increased evaporation in the downdraft so that the net change in the latent heating in the cloud with increasing aerosol is zero. This is shown in Hill et al (2008). The differences in condensation-evaporation (CE) rate between simulations with low and high aerosol occur at the cloud top and cloud base. Changes in the CE rate at cloud top will impact entrainment and entrainment warming of the cloud (not discussed in this manuscript), while changes at cloud base will effect decoupling (discussed in this manuscript). The bulk analysis will not pick up on these subtleties, yet I think that it is this change in the condensation-evaporation rate in the vertical that is important in determining the response of the cloud to increasing aerosol.

Refer to our first response above.

In addition to their discussion on decoupling due to solar radiation and cloud base evaporation, the authors need to discuss cloud top entrainment and the previous work on this topic to justify why they discount the cloud drop sedimentation and cloud top evaporation as possible causes of the change in LWP with increasing aerosol.

As described above, additional simulations showed that the interactions between supersaturation, CDNC and dynamics (and their interplay with cloud-base rain evaporation in cases with no surface precipitation) play a crucial role in making differences in the LWP, evaporative cooling and thus entrainment.

The authors need to present plots of that demonstrate the underlying mechanisms relative to those suggested in previous work. It would be useful to see vertical profiles of CE rates as this is an important variable when considering the effect of aerosol induced competition for water vapour.

As shown in additional simulations and as discussed in our responses above, the interplay among CDNC, supersaturation and dynamics (and their interactions with cloud-base rain evaporation in cases with no surface precipitation) play the most important role in aerosol-cloud interactions and their dependence on the intensity of solar radiation. This interplay and its interactions with cloud-base rain evaporation (and thus cloud-base instability) determine the condensation variation which controls the LWP, evaporation and thus entrainment variation between the high- and low-aerosol runs.

If you see equation (2), the cumulative condensation minus cumulative evaporation is equal to the conversion (i.e., autoconversion + accretion) plus cloud liquid amount suspended at the end of time integration; in case there is no suspended cloud liquid at the end of time integration, the cumulative condensation minus cumulative evaporation is equal only to the conversion (i.e., autoconversion + accretion). The cloud liquid amount suspended at the end of time integration is represented by the storage term on the left hand side of equation (2); if we insert $\frac{\partial q_c}{\partial t}$ in (1), we can see the meaning of the domain-averaged cumulative value of $\frac{\partial q_c}{\partial t}$ more clearly. $<\frac{\partial q_c}{\partial t}>$ is just the averaged LWP of suspended cloud liquid at the end of the simulations in case there is no suspended cloud liquid at the beginning of the simulations. In case there is suspended cloud liquid at the beginning of the simulations, $<\frac{\partial q_c}{\partial t}>$ is the difference in the averaged LWP of suspended cloud liquid between the end of the simulations and the beginning of the simulations. Hence, condensation minus evaporation does not give us any information about the relative importance of terms associated with cloud liquid. The traditional concept proposed by Albrecht stated that the conversion controlled the response of LWP to aerosol changes. This study indicates that the source of LWP (i.e., condensation) plays much more important roles in this response than the conversion and determines the variation in evaporation and entrainment.

3) The paper presents some sensitivity simulations in which the downwelling solar radiation is increased by half, reduced by a factor of 2 and a factor of 5. I think these tests are interesting numerical experiments but I am struggling to see the point of them as they are not well justified. As this paper revolves around an aerosol induced condensation effect, the authors have not presented a full set of results to back-up their conclusions from these sensitivity runs. By changing the downwelling solar radiation, the cloud top heating rate will change, which in turn will influence the cloud top entrainment. Nothing is presented or discussed on this issue.

Our intention was to examine the variation of the aerosol-cloud interactions in thin stratocumulus clouds with the variation of the incident solar radiation whose magnitude nearly corresponds to that of latitudinal variation of the incident solar radiation in July, if only the variation among CONTROL, SW-D2, and SW-D5 (excluding SW-M1.5) is considered. The incident solar radiation in SW-M1.5 is an idealized one, since it is larger than the observed maximum incident solar radiation in July. SW-M1.5 is generated to examine how mechanisms which control aerosol-cloud interactions with no surface precipitation vary with solar radiation with the comparison to CONTROL.

The following (between dashed lines) is added:

(LL195-200 in p7)

The range of the averaged SW among CONTROL, SW-D2, and SW-D5 in Table 1 nearly corresponds to the magnitude of the latitudinal variation of the averaged SW over the daytime in July. The averaged SW in SW-M1.5 which is larger than that in CONTROL enables the examination of the aerosol-cloud interactions in shallower clouds than those in CONTROL. This is because the decoupling in the MBL generally increases with increasing incident solar radiation.

As shown in the additional experiments with the CDNC fixed and the sedimentation turned off, the difference in condensation and LWP is accounted for by the CDNC difference controlling the interactions among CDNC, supersaturation, and dynamics for each of cases with the surface precipitation and by the interplay between the effect of the CDNC difference on condensation and the effect of rain evaporation on cloud-base instability for each of cases with no surface precipitation. These interactions for cases with the surface precipitation (and interplay for cases with no surface precipitation) controlled the entrainment and its variation with aerosols in each of cases.

Furthermore, if the changes in cloud microphysics due to increasing aerosol feed into the radiation calculation, then increasing aerosol will lead to a different vertical profile of solar heating. These differences could be influencing the results of the sensitivity runs yet nothing is mentioned about this. As this paper concentrates on solar radiation it is important to discuss influence of solar radiation on cloud top as well as cloud base, particularly when changing the downwelling solar radiation.

As shown in the additional experiments with the CDNC fixed, the difference in LWP is controlled by interactions among CDNC, supersaturation, and dynamics for cases with the surface precipitation; when CDNC is fixed for condensation, the difference in LWP between the high- and low-aerosol runs becomes negligible for cases with the surface precipitation. But due to more vapor transportation with less decoupling, SW-D5 shows larger LWP in both the high- and low-aerosol runs than SW-D2.

For the cases with no surface precipitation, the additional experiments with no rain evaporation and sedimentation showed that the high-aerosol run had higher LWP due to the absence of rain evaporation around cloud base. When the CDNC is fixed and rain sedimentation and evaporation are deactivated for cases with no surface precipitation, the difference in LWP between the high- and low-aerosol runs almost disappears. But SW-M1.5 shows smallest LWP due to the strongest decoupling among cases and CONTROL shows second smallest LWP due to the second strongest decoupling in these additional simulations with CDNC fixed and no rain sedimentation and evaporation.

The intensity of solar radiation determines the level of LWP varying over the cases in this study. However, in each of cases, it is the interplay among CDNC, supersaturation and dynamics and its interactions with cloud-base instability that controls the LWP variation with varying aerosols.

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