Response to Reviewer #1:

General comments:

This study examines the behavior of different microphysics schemes used in climate models that take into account the relative dispersion effect in different ways, and explores the sensitivity of the model-simulated cloud and radiation fields to different representations of the dispersion enhancement with increasing aerosols. The results show that the aerosol indirect forcing becomes reduced significantly when incorporating the aerosol-induced increase of the relative dispersion. It is also shown that the reduced magnitude of the indirect forcing depends on choice of the scheme with different sensitivities of the dispersion to droplet number concentration. This is a useful addition to estimates of the aerosol indirect effect, particularly by means of climate modeling. The study is also (at least qualitatively) consistent with a growing body of knowledge that tends to indicate that the aerosol indirect forcing might be smaller than what has been considered in the past. The important contribution of this study, I think, is a quantitative estimate of how much aerosol indirect forcing can be reduced by the relative dispersion effect. I would recommend the paper be accepted for publication in Atmos. Chem. Phys. after my following concerns are adequately addressed.

Response: Thanks for the positive comments.

Specific points:

Page 2, Line 19-20: "ε is increased by anthropogenic aerosols under similar dynamical conditions in clouds." Why does the relative dispersion increase with increasing cloud droplet number concentration? Please explain the basic mechanisms for it, not just providing a reference to previous studies that showed such tendencies.

Yes, we have added the explanations in the revised manuscript: *"Liu and Daum (2002) suggested that ε is increased by anthropogenic aerosols under similar dynamical conditions in clouds, because more numerous small droplets formed in polluted clouds compete for water vapor and broaden the droplet size distribution compared with clean clouds having fewer droplets and less competition. Further theoretical* *study (Liu et al., 2006) revealed that the increased ε is primarily due to slowdown of condensational narrowing associated with decreased supersaturation."*

Page 5, Line 21-23: "The difference between the simulations with the same ocean surface conditions but aerosol emissions for PD and PI was used to calculate the changes in cloud microphysical properties and cloud radiative forcing induced by anthropogenic aerosols in Section 4." It seems that the aerosol indirect radiative forcing (AIF) thus obtained is the effective radiative forcing that is a "net" radiative forcing remaining after the rapid adjustment occurs, rather than an instantaneous radiative forcing. Is this correct? If so, the authors should clarify that this is the effective radiative forcing, not the instantaneous radiative forcing, because these two are remarkably different in their representations as a climate driver (IPCC AR5, Chapter 7). Even in that case, the reviewer is a bit confused by the author's definition of the indirect radiative forcing (AIF): To the reviewer's understanding, the first indirect effect is categorized into the instantaneous radiative forcing while the second indirect effect is categorized into the effective radiative forcing. The authors, however, tend to define the first and second indirect forcings due to perturbations to Reff and LWP, respectively, in the same configuration of the prescribed SST. Should I interpret the AIF as the total effective radiative forcing due to aerosol-induced perturbation to clouds? I would much appreciate the reviewer to clarify these points.

Thanks for this great point. In our manuscript, the combined first and second indirect forcing is the effective radiative forcing, not instantaneous radiative forcing. The AIF is the combined first and second indirect forcing, which is the total effective radiative forcing due to aerosol-induced perturbation to clouds including the first and second indirect effects. Hence, we have clarified in our manuscript *"Note that the AIF is the combined first and second indirect forcing, which is the effective radiative forcing (net TOA radiative fluxes to perturbations with rapid adjustments), not instantaneous radiative forcing, following IPCC (2013)."*

Page 6, Last paragraph: It is shown that the cloud droplet number concentration is underestimated while the effective radius agrees with satellites. How should I interpret these apparently inconsistent results? – Does this mean that the cloud water content is also underestimated?

Yes, "the simulated cloud droplet number concentration is underestimated in CAM5.1 model while the effective radius agrees with satellites" is right. This apparent insistency could arise from underestimated cloud water content. Unfortunately, we do not have observed cloud water content to verify this point (Gettelman et al., 2015). To accommodate this point, we add in revision *"It is noted that the simulated cloud droplet number concentration is underestimated in CAM5.1 model while the effective radius agrees with satellites. This apparent inconsistency suggests that the simulated liquid water content may be somehow underestimated. Unfortunately, we do not have observed cloud water content to verify this (Gettelman et al., 2015)."*

Page 7, Line 8-11: Can these biases in SWCF and LWCF be interpreted in terms of biases in occurrence of different heights of clouds (low, middle and high clouds)? It would be useful to show cloud cover for low, middle and high clouds, as well as the total cloud cover, in Table 2.

Thanks for the suggestions. We have added the statistical properties for low, middle and high clouds at the global scale in Table 2, and we also have added some interpretations about SWCF and LWCF in the terms of low, middle and high clouds in the revised manuscript.

Table 2. Annual global mean aerosols, cloud properties, and surface precipitation, as well as TOA energy budget with year 2000 aerosol emissions including aerosol optical depth at wavelength 550 nm (AOD), liquid water path (LWP), Ice water path (IWP), the vertical integrated cloud droplet number concentration (N_d), cloud top effective radius (REL), total cloud fraction (CLDTOT), low cloud fraction (CLDLOW), middle cloud fraction (CLDMED), high cloud fraction (CLDHGH), total precipitation rate (P_{tot}), shortwave cloud radiative forcing (SWCF), and longwave cloud radiative forcing (LWCF).

Simulation	Old	New1	New2	New3	New4	OBS
AOD	0.121	0.122	0.122	0.124	0.125	0.15^a
LWP, g m^{-2}	44.74	36.76	40.33	37.62	43.48	–
IWP, g m^{-2}	17.78	18.70	18.88	18.84	18.96	–
N_d, 10^{10} m^{-2}	1.38	1.33	1.40	1.35	1.47	4.01^b
REL, μm	9.21	11.48	10.87	11.32	10.08	10.5^b
CLDTOT, %	64.02	65.50	65.63	65.74	65.82	$65-75^c$
CLDLOW, %	43.61	44.88	45.25	45.31	45.47	–
CLDMID, %	27.27	27.58	27.67	27.65	27.72	–
CLDHGH, %	38.09	39.24	39.09	39.22	39.16	$21-33^d$
P_{tot}, mm day^{-1}	2.96	2.97	2.97	2.97	2.97	2.67^e
SWCF, W m^{-2}	−52.08	−49.82	−52.40	−51.01	−53.03	-47.07^f
LWCF, W m^{-2}	24.06	25.23	25.40	25.37	25.51	26.48^f

[a] AOD is from a satellite retrieval composite (Kinne et al., 2006), [b] N_d and REL are from the AVHRR data (Han et al., 1998). [c] CLDTOT is obtained from ISCCP (Rossow and Schiffer, 1999), MODIS data (Platnick et al., 2003), and HIRS data (Wylie et al., 2005). [d] CLDHGH is obtained from ISCCP data (Rossow and Schiffer, 1999) and HIRS data (Wylie et al., 2005). [e] P_{tot} is taken from the Global Precipitation Climatology Project (GPCP) for the years 1979−2009 (Adler et al., 2003). [f] Radiative fluxes from the CERES-EBAF are for the years 2000−2010 from Loeb et al. (2009).

Minor points: I found some grammatical errors/typos as follows. Hope this helps the authors improve English.

Thank you very much for your kindness. We have checked it and tried our best to correct all the errors/typos.

Page 5, Line 4: “as detailedly described by Neale et al. (2010)” -> “which is documented in Neale et al. (2010)”.

Taken.

Page 5, Line 13: “here” -> “where”

Taken.

Page 9, Line 13: “PL on Nc” -> “PL with increasing Nc”.

Taken.

Page 9, Line 20: These results can also *be* seen: : :

Taken.

References

Gettelman, A., Morrison, H., Santos, S., Bogenschutz, P., and Caldwell, P. M.: Advanced two-moment bulk microphysics for global models. Part II: global model solutions and aerosol-cloud interactions, J. Climate, 28, 1288–1307, doi:10.1175/JCLI-D-14-00103.1, 2015.

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