We thank two anonymous referees for their valuable comments to the manuscript and their constructive suggestions. Below, we explain how the comments and suggestions are addressed and make note of the revision we made in the manuscript.

Anonymous Referee #1

General comments:

This article tests 2 parameterizations for dust aerosols emissions, 2 dust transport treatments, and 2 dust aerosol size distribution in the regional WRF model against a wide array of measurements in North Africa. The article is well-written, clearly presented, and presents results that are important to the dust modeling community. For example, the authors show that the WRF/Chem model has skill in reproducing observed dust emissions and can thus be used in future studies. Moreover, the dust emission and dust transport schemes are varied in this study, which is useful in assessing their relative effect.

The article thus attempts to accomplish two separate goals. First, it tests parameterizations for dust aerosol emissions in WRF/Chem, a commonly used regional model. Second, it runs several cases to test the influence of the dust emission scheme, size distribution and modal or bin transport method on the predicted dust concentration, optical depth, etc. The paper clearly meets the first goal, which makes it an important contribution to the literature. However, it falls short of the second goal for reasons I note below. I envision the article will be suitable for publication in ACD after substantial revisions.

We thank the reviewer for a detailed review and his/her constructive comments on this work. Both text and figures are revised as the reviewer suggested.

Specific comments:

- ***The article presents results of 4 separate runs, with different emission schemes, emitted dust distributions, and transport (modal vs. sectional) schemes. However, only 2 of these runs (Modal1-G and Sect1-D) are tuned to measurements, whereas the other 2 (Modal2-G and Sect1-G) are not (that is, the total emitted mass is kept the same as in the Modal1-G run, even though the dust size distribution, which***

greatly affects the dust optical depth and other measures, is varied substantially). The asymmetry in the tuning of the 4 runs makes the comparison between them of reduced value. Although the authors can still draw conclusions about the general effect of the different dust emission, transport, and size distribution parameterizations, they cannot draw firm conclusions about which one compares better with measurements. For example, the correlation coefficients of the 2 untuned runs with AOD measurements (Figure 7) are much lower than for the tuned runs, but it's impossible to say whether this is because of the lack of tuning for the former 2 runs or because the size distribution (or transport scheme) is less realistic. And being able to conclude which size distribution and transport scheme is preferable would be important to optimizing future dust models. I thus recommend that the authors redo runs Sect1-G and (especially) Modal2-G and tune the parameter C in the same manner that they tune it for runs Modal1-G and Sect1-D. The authors will then be able to draw conclusions on which transport scheme and (especially) size distribution parameterization compares better with measurements. Because of the broad range of measurements used by the authors, this would be of value to the literature and would greatly improve the article.

Originally, our study tuned the *C* values in Sect1-G and Sect1-D to the AERONET measurements. Modal1-G has the same total dust mass emission and initial size distribution as Sect1-G as we stated in the model description section "When estimating the size distributions of emitted dust, we estimate the log-normal size distribution for the MADE/SOGAM aerosol model first, and then integrate the mass following the log-normal size distribution into the eight size bins in the MOSAIC aerosol model, to make the size distributions of emitted dust consistent between the two aerosol models." Therefore, the difference between Modal1-G and Sect1-G is solely from the difference between the two aerosol size treatments in the two cases with all other underlying conditions same. So we keep the *C* value in Modal1-G the same as that in Sect1-G.

For Modal2-G, we think the reviewer has a good point. We now redo the simulation in Modal2-G case with the re-tuned *C* value of 0.40 $\mu g\ s^2\ m^{-5}$, which makes Modal2-G simulated average AOD generally consistent with that from Modal1-G. This makes the difference between Modal1-G and Modal2-G is solely from the difference between their size distributions of emitted dust.

Now we clarify the tuning of *C* values in the text as "The *C* values in dust schemes are tuned differently for different cases. For GOCART scheme, the *C* value is tuned to 0.65 μg s^2 m^{-5} based on Sect1-G results and kept the same for Sect1-G and Modal1-G because they have the same total amount and size distributions of emitted dust. The *C* value in Modal2-G is tuned differently to 0.40 μg s^2 m^{-5} to make Modal2-G simulated AOD similar to that from Modal1-G over the dust source region, because Modal2-G has a different size distribution of emitted dust, which can greatly affect the dust optical depth. For the DUSTRAN scheme, the *C* value is tuned to 0.33×10^{-14} g cm^{-6} s^{-3} based on Sect1-D results. The original *C* values are 1.0 μg s^2 m^{-5} in Ginoux et al. [2001] and 1.0×10^{-14} g cm^{-6} s^{-3} in Shaw et al. [2008]." and the abstract is also updated with "Simulations using the GOCART scheme with different initial (emitted) dust size distributions require ~40% difference in total emitted dust mass to produce similar SW radiative forcing of dust over the Sahel region." and the conclusion is updated with "Because of the tuning of the *C* parameter to make model simulated AOD consistent with the measurements, the total amount of dust emissions is sensitive to the size distributions of emitted dust, which results in that the total emitted dust amount for the simulation period changes from 200 Tg for the case with more larger dust particles to 124 Tg for the case with more smaller dust particles." and "The simulated dust concentration is also sensitive to the size distributions of emitted dust. In order to simulate similar AOD, the model with more dust particles emitted into the submicron regime (radius < 1μm) requires 40% less of emitted total dust mass and hence simulates 14% lower near-surface (< 1 km) dust concentrations on domain average. However, it's noteworthy that the size distribution of emitted dust does not significantly change the spatial distribution of the dust SW radiative forcing and also the optical properties of dust (e.g., SSA) in this study."

- ***The authors find that the modal approach retains more fine dust particles than the sectional approach. Why is that? And can this be interpreted as a deficiency of the modal approach? That is, if one would perform an idealized simulation (for example by using a very large number of bins in the sectional approach) would the modal approach deviate substantially from it?***

The difference between modal and sectional approaches can be explained by limited number of modes and also prescribed geometric standard deviation (σ_g) for each mode in the modal approach, which results in the difference of the aerosol dry deposition rates between modal and sectional approaches. In our model, although the fundamental processes of aerosol dry deposition are parameterized in the same way for both modal and sectional approaches, the prescribed σ_g for each mode could cause bias in calculating the aerosol dry deposition rate for that mode. Our sensitivity tests show that the calculated dry deposition rate is sensitive to the prescribed σ_g for each mode in the model. A change of σ_g could result in a change of the dry deposition rate in that mode. Our results show that, compared to the sectional approach, the modal approach simulates a smaller dry deposition rate for fine particles but a larger dry deposition rate for coarse particles with the σ_g obtained from the measurements (i.e., σ_g=2.2 for accumulation mode and σ_g=1.75 for coarse mode). That explains that why the modal approach retains more fine dust particles than the sectional approach in our simulation. Several sensitivity tests with different σ_g (σ_g=1.6-2.5) for accumulation and coarse modes show that the adjustments of σ_g could make the size distribution from modal approach better or worse versus measurements. The quantitative analysis of the bias from the prescribed σ_g in simulating aerosol size distribution will be in the scope of our future study.

It is very likely that a large number of bins in sectional approach will give more realistic results than the modal approach, however the computation cost prohibit such long-term WRF-Chem simulations. In our study, we find 8-bin is enough to reasonably describe the dust transport.

Now we add the text in section 4.2 “The poorer performance of the modal approach, in terms of simulating size distributions of dust, may result from its limited number of modes (only two, accumulation and coarse), and the use of constant geometric standard deviation σ_g. In our model, although the fundamental processes of aerosol dry deposition are parameterized in the same way for both modal and sectional approaches, the prescribed σ_g for each mode could cause bias in calculating the aerosol dry deposition rate for that mode. Our sensitivity tests show that the dry deposition rate is sensitive to the prescribed σ_g for each mode in the model. The modal approach retains more fine dust but less coarse dust versus the sectional approach with current values of σ_g (i.e., σ_g=2.2 for accumulation mode and σ_g=1.75 for coarse mode), because it simulates a smaller dry deposition rate for fine particles but a larger dry deposition rate for coarse particles, compared to the sectional approach. Several sensitivity tests with different σ_g (σ_g=1.6-2.5) for accumulation and coarse modes show that the adjustments of σ_g could make the size distribution from modal approach better or worse versus measurements. The quantitative analysis of the bias from the prescribed σ_g of modal approach in simulating aerosol size distribution will be in the scope of our future study."

- ***Page 10, lines 7-13: Please briefly summarize the SW dust treatment in the model, since it is critical to interpreting the results of this study.***

Following the reviewer comment, we now add the text in model description section "The aerosol optical properties such as extinction, single-scattering albedo, and the asymmetry factor for scattering are computed as a function of wavelength and three-dimensional position. Each chemical constituent of the aerosol is associated with a complex index of refraction. The refractive index is calculated by volume averaging for each size bin (or mode), and Mie theory is used to estimate the extinction efficiency (Q_e) and the scattering efficiency (Q_s). To efficiently compute the Q_e and Q_s, WRF-Chem has used a methodology described by Ghan et al. [2001], which performs full Mie calculations once first to obtain seven sets of Chebyshev expansion coefficients, and later on, the full Mie calculations are skipped and the Q_e and Q_s are calculated using bilinear interpolation over the seven sets of stored Chebyshev coefficients. A detailed description of the computation of aerosol optical properties in WRF-Chem can be found in Fast et al. [2006] and Barnard et al. [2010]."

- ***Page 12, lines 9-12: The authors keep the geometric standard deviation of the modeled log-normal modes constant. I understand that this is necessary for computational reasons, but the authors should discuss what inaccuracies are introduced into the simulation because of it. Does it explain the differences between***

the modal and sectional approaches? For example, differential particle removal rates will surely affect both the geometric standard deviation and the volume mean diameter. Also, is the volume mean diameter also held constant or does it decrease in the model as the aerosols age and the larger particles fall out? If so, how is the decrease in the volume mean diameter calculated?

We keep the geometric standard deviation constant as most current aerosol models with the modal approach do due to the computational reasons. The model does have bias from the constant geometric standard deviation. Our sensitivity tests show that the dry deposition rate is sensitive to the prescribed σ_g for each mode in the model. Several sensitivity tests with different σ_g (σ_g=1.6-2.5) for accumulation and coarse modes show that the adjustments of σ_g could make the size distribution from modal approach better or worse versus measurements. The varied σ_g could improve the simulated results from the model approach. The quantitative analysis of the bias from the prescribed σ_g in simulating aerosol size distribution will be in the scope of our future study. Now we add the text in section 4.2 "The poorer performance of the modal approach, in terms of simulating size distributions of dust, may result from its limited number of modes (only two, accumulation and coarse), and the use of constant geometric standard deviation σ_g. In our model, although the fundamental processes of aerosol dry deposition are parameterized in the same way for both modal and sectional approaches, the prescribed σ_g for each mode could cause bias in calculating the aerosol dry deposition rate for that mode. Our sensitivity tests show that the dry deposition rate is sensitive to the prescribed σ_g for each mode in the model. The modal approach retains more fine dust but less coarse dust versus the sectional approach with current values of σ_g (i.e., σ_g=2.2 for accumulation mode and σ_g=1.75 for coarse mode), because it simulates a smaller dry deposition rate for fine particles but a larger dry deposition rate for coarse particles, compared to the sectional approach. Several sensitivity tests with different σ_g (σ_g=1.6-2.5) for accumulation and coarse modes show that the adjustments of σ_g could make the size distribution from modal approach better or worse versus measurements. The quantitative analysis of the bias from the prescribed σ_g of modal approach in simulating aerosol size distribution will be in the scope of our future study."

We do predict the volume mean diameter, which means it's changed during the simulation. We predict both number and mass concentrations of the aerosols in each mode. Volume mean diameter for each mode is calculated from model predicted mass and number concentrations. We clarify it in the model description section "The volume mean diameters of the two modes are updated from the predicted aerosol mass and number concentrations during the simulation."

- ***Page 13, lines 19-20: The simulated total emission over 31 days (if I counted correctly) for Notrth Africa is ~200 Tg. That seems rather large compared to global model estimates of ~2000 Tg/year (see for example Cakmur et al., JGR, 2006), and is also large compared to the ~1800 Tg/year of Ginoux et al. (2001), who developed the main dust emission schemes used in this study. This is especially surprising considering that the tuning parameter C is 35% smaller in this study than in Ginoux et al. (2001). So why is the modeled dust emission seemingly so much larger in this study than in Ginoux et al. (2001)? Was it a particularly dusty period, does the increased resolution produce increased emission, or is there another reason?***

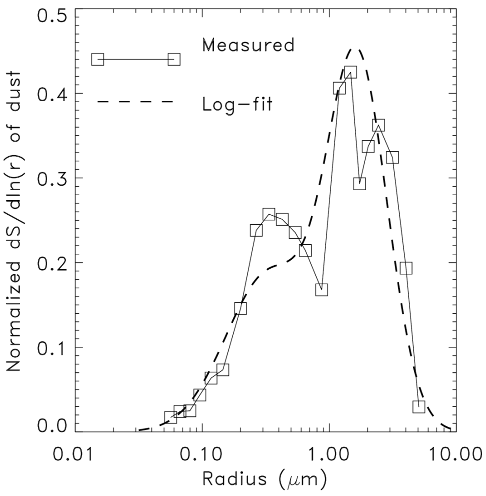
Compared to Ginoux et al. [2001], it's not surprising that we have different dust emissions although we use a similar formula for dust flux calculation. We have accessed to dust emissions that Ginoux et al. provided for IPCC model inter-comparison activities in 1999. For these emissions, the North African emissions were about 34% of the global annual total, and the North African emissions in January were about 70 Tg. The main reason for the higher emissions in our study is, we believe, because we treat emissions for dust particles with radius range of 0.1-10 μm, which is different from 0.1-6 μm in Ginoux et al. [2001]. From Fig. 3, one can see that the Modal1 emissions peak at about 4 μm radius, and the emissions between 6-10 μm are an important part of the total. For our Modal2 emissions, the peak is at about 2 μm radius, and the difference from emissions of Ginoux et al. is smaller. Also, we could have different soil moisture and especially surface wind fields in this study with a regional model having a higher horizontal resolution compared to GOCART model.

In this study, we avoid model-to-model comparisons because dust scheme is only one of many areas that the model setup in this study differs from other studies. And also, there is no previous studies report the total dust emissions over the same region (North Africa) and during the same period (January-February 2006). A detail comparison to other models would require a separate paper.

- ***Page 14, lines 21-23 and Figure 5: Please show the original data from Osborne et al. (2008) in the figure, not the fitted function.***

We show the fitted line constructed of log-normals because this is in fact more useful and realistic representation of the measurements. Now we explain it in section 3.1 "During the DABEX, the size distributions of particles between 0.05 and 1.5 μm in radius were measured by the Passive Cavity Aerosol Spectrometer Probe 100-X (PCASP) mounted externally under the aircraft wing. Particles larger than 1.5 μm were measured using PCASP-X mounted inside the aircraft cabin that used a counter flow virtual impactor (CVI) inlet operating in a passive aerosol mode [Johnson et al., 2000; Osborne et al., 2008]. The raw data from the instrumentation contains some noise and bin-to-bin fluctuations due to the difficulties of assigning counted particles to the correct size bin. The in-situ probes measure scattered signal and relate this to particle size through a set of assumptions and Mie theory. In some regions of the size spectrum there is not a unique relationship between scattered signal and particle size (multiple sizes can theoretically give the same signal amplitude due to the phenomena of optical resonance). Therefore, the fitted line was constructed of log-normals instead of the raw data to show size distributions of particles [Osborne et al., 2008]. The log-normals naturally smooth over some of these instrumental features and are therefore more realistic of the real aerosol size distributions. The fitted line is used in the comparison with model results in this study."

We, here, show the plot of the raw data. Although the fitting does not capture the peak at 0.3 microns quite well, as you can see that the raw data is quite noisy and not every fluctuation should be trusted and captured exactly.



Technical Comments:

- ***Abstract, line 20-25: the authors mention maximum heating rates and radiative forcings here. Those are much more noisy and of less use than averages. Please replace maximum rates by domain average rates.***

For heating rate, we showed the profile averaged over the Niamey vicinity for the DABEX period. Now we change the text in abstract to "the mineral dust heats the lower atmosphere with an average rate of 0.8±0.5 K day^{-1} over the Niamey vicinity and 0.5±0.2 K day^{-1} over North Africa and reduces the downwelling SW radiation at the surface by up to 58 W m^{-2} with an average of 22 W m^{-2} over North Africa."

- ***Page 3, lines 5 and 10: The authors use "Sahara" on line 5 and "Sahel" on line 10. Is this intentional or do the authors mean to refer to the same geographic area?***

We change "Sahelian dust" in line 10 to "Saharan dust".

- ***Page 3, line 21-22: The recent study by Balkanski, ACP, 2007 would be appropriate to cite here.***

Balkanski et al. [2007] is cited here and added into reference list.

- ***Page 3, line 25-26: Readers might not be familiar with the processes of saltation, creep, and suspension, and these should be defined and an appropriate reference should be cited.***

Now we clarify it as "Dust emission fluxes are widely modeled through parameterizations of suspension (by which soil particles are suspended into the air), saltation (sand blasting) and creeping (slow progression of soil and rock) processes associated with wind erosion [Bagnold et al., 1941]." Bagnold et al. [1941] is cited and added into the reference list.

- ***Page 4, lines 4-5: Readers might not be familiar with the modal and sectional transport approaches. Please define them here, and discuss their benefits and drawbacks, which will also make the rest of the article easier to follow.***

Following the reviewer comment, we have added the text in introduction section "A modal approach represents the size distribution of aerosols by several overlapping intervals, called modes, normally assuming a log-normal distribution within each mode, while a sectional approach represents the size distribution of aerosols by several discrete size bins, which are defined by their lower and upper dry particle diameters. Generally speaking, a modal approach is less accurate because of its assumption of log-normal distribution and limited number of modes, but it is computationally cheaper than a sectional approach that uses more bins."

- ***Page 5: lines 18-25: The relation of DABEX to AMMA is unclear to me here. Is one a subset of the other or are they separate field campaigns?***

DABEX is a subset of the AMMA campaigns for dry season. Following the reviewer comment, we now clarify in the text as "The Dust and Biomass-burning Experiment (DABEX) is a United Kingdom (UK) Met Office led field campaign involving the UK FAAM aircraft to investigate the properties of mineral dust and biomass burning aerosols over North Africa in the vicinity of Niamey, Niger from 13 January to 3 February in 2006 (referred to as the DABEX period hereafter). It coincided with the dry season special observing period (SOP-0) of the African Monsoon Multidisciplinary Analysis (AMMA) [Redelsperger et al., 2006]. The flights of the FAAM aircraft were coordinated with ground observations and an ultra-light aircraft that were deployed as part of AMMA-SOP-0 [Haywood et al., 2008].”

- ***Page 6, line 5: Please define “nephelometer”***

“nephelometer” is an instrument for measuring suspended particulates in a liquid or gas colloid. We now explain it in the text.

- ***Organizational comment: I think the article would be better organized if the authors first present their methods (i.e., chapter 3), and then the data they use to test their methods (i.e., chapter 2). That is, I recommend they switch chapters 2 and 3.***

Switched.

- ***Figure 4: The x-axis here is confusingly labeled. Please include the actual dates and mention them in the caption.***

Corrected.

Anonymous Referee #2

General comments:

In this sensitivity study, two aerosol models and two emission schemes are applied and tested for their ability to simulated the spatial distribution of mineral dust, size distributions, and SW radiative forcing over North Africa. The manuscript is well written and structured, and, generally, fulfils the requirements for publication in ACP. I have only some minor comments which I would like the authors to consider.

We thank the reviewer for a detailed review. Both text and figures are revised as the reviewer suggested.

Technical Comments:

- ***P9757 line 21: Include a reference for DABEX. Also, how DABEX and AMMA are linked is not clear.***

Now we clarify in section 3.1 as "The Dust and Biomass-burning Experiment (DABEX) is a United Kingdom (UK) Met Office led field campaign involving the UK FAAM aircraft to investigate the properties of mineral dust and biomass burning aerosols over North Africa in the vicinity of Niamey, Niger from 13 January to 3 February in 2006 (referred to as the DABEX period hereafter). It coincided with the dry season special observing period (SOP-0) of the African Monsoon Multidisciplinary Analysis (AMMA) [Redelsperger et al., 2006]. The flights of the FAAM aircraft were coordinated with ground observations and an ultra-light aircraft that were deployed as part of AMMA-SOP-0 [Haywood et al., 2008]."

- ***P9759/9760: In the description of the satellite products it would be useful to discuss the overpass times of Terra (MODIS, MISR) and Aqua (MODIS). For instance, if MODIS samples a certain location only in the afternoon but emission occur mostly in the morning (e.g. frequently observed for low level jet related emissions in North Africa) then biases in the AOD product are expected. This should be discussed with respect to the comparison between model AOD and satellite-derived AOD presented in this paper (e.g. Fig 7). It is stated later (P9768 line10) that the "Model results are sampled in the same overpath with satellites".***

The overpass times of the two satellites are added in the data description section. We clarify in section 3.4 and 3.5 as “The MODIS on board the Aqua platform passes over the equator at ~13:30 LT during the daytime [Kaufman et al., 1997]. When comparing model simulated AOD with MODIS retrievals, model results are sampled in the same overpass time as Aqua.”, and “The MISR on board the Terra platform passes over the equator at ~10:45 LT during the daytime [Diner et al, 2001]. When comparing model simulated AOD with MISR retrievals, model results are sampled in the same overpass time as Terra.”, in which way the comparisons between model and satellites are apple-to-apple.

- ***P9761 line 24: A short explanation why the meteorological conditions need to be reinitialized every 5 days would be useful.***

In this study, our purpose is to forecast dust other than to study the dust impact on climate. The re-initialization can reduce the bias from the meteorological simulation. Now we add the text in model description section “The re-initialization of meteorological conditions can reduce the bias in meteorological simulations.”

- ***P9761 line 28: It would be useful to outline the 170x120 box in one of the maps. In general, it is difficult for the reader to visualize which region is covered by a 200x150 grid with 36km resolution centered over Niamey. Lat/Lon boundaries would be helpful.***

All the maps shown in the paper are for 170×120 grid points. Now we add lat/lon boundaries in the text “Only the simulated results at the 170×120 interior points (28.9^{o}W-32.9^{o}E, 5.0^{o}S-32.1^{o}N) of the horizontal domain (200×150 grid points) (36.15^{o}W-40.15^{o}E, 9.2^{o}S-37.0^{o}N) are used for analysis to minimize the potential spurious anomalies from the lateral boundary conditions.”

- ***Section 3.1: It might be interesting for some readers which land surface model and PBL physics were used in the WRF/Chem model setup.***

Added in section 2.1 as “The Noah land surface model and Mellor-Yamada-Janjic Planetary Boundary Layer (PBL) scheme are used.”

- ***Fig 1, caption: Ginoux et al. (2001) reference should be included for the source function.***

Added.