# Reply to anonymous referee #1

We would like to thank the Editor and the second Reviewer for the thoughtful and insightful comments. We have addressed all the comments. Our responses are itemized below.

General:

In this study, by online coupling the GEOS-Chem global three-dimensional chemical transport model (3-D CTM) with the Fu-Liou-Gu (FLG) radiative transfer code, the more realistic dust vertical profiles can be directly provided to FLG besides the "climatological" one (i.e., FLG vertical profile). And then the authors fully investigated the important roles of vertical profiles in the dust direct radiative forcings and heating rates, along with the differences between these two dust vertical profiles. They found out that using the GEOS-Chem vertical profile can reflect the differences of vertical structure of AOD between dust and non-dust source regions, while this is missed if the FLG vertical profile is used. The obvious differences in radiative forcings and heating rates due to different dust vertical profiles used emphasize the importance of vertical profiles in radiative forcing calculations, and hence in modulating regional circulation. The manuscript overall is well written, although I felt more clarifications are needed. I suggest that this manuscript will be able to be published if the authors address the minor revisions indicated below.

1. In page 2422, Line 15-20, the authors have mentioned that the spatial variations of solar zenith angle are not taken into account and the cosine of the solar zenith angle of 0.5 is used in the calculations. I feel confused that whether the constant value of 0.5 is globally used? And how about the temporal resolution for radiation calculations? Is 6-h used? If so, any temporal variations of solar zenith angle are considered? If no temporal and spatial variations of solar zenith angle are included into the radiation calculations, the global estimate for monthly mean results can't be taken as the true representations for the global monthly-mean effects of the dust vertical profiles. More explanations about this are suggested to better support the authors' conclusions.

Response: The Reviewer is correct that the global estimate of monthly mean aerosol forcings may not be very accurate when the cosine of the solar zenith angle ($\mu_0$) of 0.5 is used globally. However, our paper focuses on the sensitivity of radiative forcing to dust vertical profiles. The cosine of solar zenith angle only affects the available solar flux at the top of the atmosphere (TOA). The spatial and temporal variations of the solar flux at TOA due to variation in $\mu_0$ would be the same in the two simulations using different vertical aerosol profiles. Therefore, differences in the results between the two simulations would basically eliminate the possible effect due to solar zenith angle variation. Also, it has been a common practice to use a cosine of the solar zenith angle of 0.5 and a 12-hr solar day to estimate solar radiative forcing using prescribed cloud or aerosol fields (e.g., Fu and Liou 1993; Gu et al. 2012). We have incorporated additional descriptions and explanations in the revised version. See Page 11: L21 ~ Page: L13.

2. There are some inconsistencies among Fig.4 and Fig.5. For example, in Fig.5, over 5°W-60°E, below 800hPa, for all dust sizes over both Africa and Asia dust belts, all the differences are positive, however, in Fig.4, the corresponding differences are negative. Please double check these two plots.
Response: We thank the Reviewer for pointing out the inconsistencies displayed in Figs. 4 and 5 (Fig. 7 and 8 in revised manuscript). We have inadvertently pasted an incorrect diagram in Fig.5 (Fig. 8 in revised manuscript), which has now been corrected (see Fig. 8 in the revised manuscript).

3. In section 4.2, in order to study the differences of solar radiative forcing over dust source regions and downwind areas, the (10°E, 20°N) and (140°E, 40°N) are selected to represent the dust source region of Sahara desert and downwind area of Eastern Asia, respectively. I just feel confused why the authors don't choose the downwind area that is adjacent to each dust source region. For example, why don't use the Africa dust belt with the Arabian Sea, or the Asian dust belt with Eastern Asian? Any explanations are appreciated.
Response: This point is well-taken. Actually, the characteristic patterns of the vertical structure in Fig. 8 and Fig. 9 (Fig. 11 and Fig. 12 in revised manuscript) over different dust source region or downwind area are quite consistent. The Sahara desert is the biggest dust source region in the world and consequently, it is the best to represent the dust source region. The downwind area of the Arabian Sea is influenced not only by the Sahara desert, but also other Asian deserts over the Arabian Peninsula as well (such as Rub Al-Khali etc.). For this reason, we have selected the location (140°E, 40°N) in the downwind area of Asian dust source region for representation, which is also an important pathway of the trans-Pacific transport. We have incorporated these explanations in the revised manuscript. See Page 20: L16-22.

4. In section 4.1, the explanations on the values listed in Table 1 are generally accompanied with Figs.3, 4 and 5. However, there exist some inconsistencies among these table and figures: the Sahara and Gobi used in Table 1 have narrower latitude spans than the African and Asian dust belts used in Fig.3, 4, and 5. So I just wonder why not the same latitude domains used for both Table 1 and Fig.3, 4, and 5. Are there any special considerations taken for these?
Response: Following the suggestion, we have included additional discussions below. The definition of Asian source region (in Figures 3, 4, and 5, now Figures 6, 7, and 8 in the revised manuscript) includes not only the Gobi desert, but also other deserts such as the Takalamekan desert in western China and deserts in the central Asia (e.g. Kara Kum desert, Maranjab desert, etc.), the deserts in the Arabian Peninsula and

Oman. We have also corrected a typo regarding the definition of Sahara desert as "the Sahara desert (10°N-35°N, 10°W-40°E)".

5. In Page 2428, some analyses are needed to explain the conclusion listed at Line 7-9.
Response: Added as "With the GEOS-Chem vertical profile, there are more solar net flux at the surface (see Fig. 11b), which results in less cooling produced over the Sahara, Gobi and Arabian Sea than that with FLG vertical profile (Table 1)."

Other minor comments:
1. It's better to include the units in the figure captions for Fig.1 (dust emission), Fig.6-Fig.14.
Response: Done.

2. In abstract, Line 15-18, this sentence should be for TOA, and the Infrared radiative forcing decreases over African dust belt, while increases over Asian dust belt, when the GEOS-Chem vertical profile is used. Clearly the more accurate description here is suggested.
Response: We have revised the text accordingly. See Page 2: L17-22.

3. In Page 2417, Line 19-20, "The vertical distribution of dust also plays an important role in serving as cloud condensation nuclei." I just wonder whether the dust instead of the vertical distribution serves as cloud condensation nuclei. So it seems that the writing needs to be modified.
Response: Revised as "The dust particles also play important roles in serving as cloud condensation nuclei [Li et al., 2011], thus their vertical distributions relative to cloud cover could impact radiative transfer. "

4. Typo error: li.zhang@colorado.edu.edu, duplicated ".edu".
Response: Corrected.

5. In Page 2425, Line 7, "from the distribution from gravitational settling", it's better to use "by gravitational settling".
Response: Changed.

6. In Page 2426, Line 24, it's better to add the unit [Wm-2] after "0 ~1".
Response: Done.

7. In Page 2427, Line 14, "A possible reason for" should be "A possible reason".
Response: Revised.

8. In Page 2430, Line 16-18, "the warming effect with GEOS-Chem vertical profile is 0.44 Wm-2 and 0.06 Wm-2 higher than that of FLG vertical profile over the

downwind area of Eastern Asia due to more dust particles in the free troposphere". There are two values (0.44 and 0.06), however, only one corresponding area is listed, i.e., the downwind area of Eastern Asia. Clearly, one more area is missed. Please modify.

Response: The text has been modified as " However, the warming effect with GEOS-Chem vertical profile is 0.44 W/m2 and 0.06 W/m2 higher than that of FLG vertical profile over the downwind area of the Eastern Asia and Asian source region (Gobi desert) due to more dust particles in the free troposphere (see Fig. 7 and Fig. 8)".