Interactive comment on “The Influence of Simulated Surface Dust Lofting Erodible Fraction on Radiative Forcing” by Stephen M. Saleeby et al.

Reviewer comments below are in standard black font, while the author responses are in blue italic font for contrast.

General reply to reviewers based on overarching comments:

We thank the reviewers for their time in examining our manuscript and offering constructive criticism, comments, and suggestions. We feel that reviewer comments have led to an improved manuscript. As will be discussed in detail below in response to specific comments and questions, this paper presents a theoretical modeling study placed in the context of a dust lofting event over the Arabian Peninsula that explores the potential radiative response to variable dust loading using dust lofting models and dust-sensitive radiation schemes embedded within sophisticated high-resolution model environments. The main goal of the paper is to examine the mean differences in radiative quantities and atmospheric temperature resulting from differences in dust loading that result from applying different dust erodible fraction datasets to the lofting model.

While the Arabian Peninsula is well-known for its expansive dust storms, few dust lofting studies have been performed over this region. This is, perhaps, because aerosol related data in this region are limited. As such, we have provided a more qualitative model comparison to the limited aerosol observations in the area in order to broadly demonstrate that one of the models (RAMS) does a favorable job in simulating dust lofting when the dust erodible fraction is constrained by geographical datasets, while noting that precisely simulating the magnitude and location of individual dust plumes is incredibly difficult. Following this, the RAMS model was then used to investigate dust radiative effects in the simulated environment. It is not our intent to determine which dataset leads to the best model representation of dust lofting. Walker et al. (2009) provide such an assessment with regards to dust lofting and surface visibility. Our focus is on determining the potential range of dust radiative effects by comparing a simulation with no-dust to those with varying amounts of dust generated by use of different specifications of surface dust erodible fraction.

Overall, we have worked to more clearly frame the focus of this paper as a theoretical examination of dust radiative effects in a case study context, while noting that dust AOD observations are limited, yet they compare favorably to RAMS simulations when dust erodible fraction appropriately constrains the amount of lofting.

<u>Anonymous Referee #2</u>

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The manuscript analyses the numerical simulations of dust lofting using erodible dust fraction as input and its impact on radiation during daytime hours and nighttime hours. The dust erodible faction is taken from dataset from three methods, namely, the “idealized”, “Ginoux”, and “Walker”. The numerical simulations are done with WRF and RAMS over the Arabian

Peninsula. Overall, the manuscript is well written, logically presented, and is interesting to read. I recommend the publication of this manuscript after considering the following suggestions:

1. I could not find any quantitative validation exercise between MODIS and Model AOD. Please clarify. Can the MODIS AOD be extracted at some of the stations and compared with Model data? It has also ben inferred in previous studies that MODIS data overpredicted AOD for regions predominant with dust (see Remer et al. 2005). Please take this into account while validation of the model. (Remer LA, Kaufman YJ, Tanré D, Matto S, Chu DA, Martins JV, Li RR, Ichoku C, Levy RC, Kleidman RG, Eck TF, Vermote E, Holben BN (2005) The MODIS aerosol algorithm, products, and validation. J Atmos Sci 62:947–973. https://doi.org/10.1175/JAS3385.1)

As reviewer 1 has pointed out, we have limited aerosol observations for validation of this dust event. We have included the two MODIS aerosol retrievals during this event that had the best available domain coverage. In the discussion of the MODIS data we cited that the retrievals have an uncertainly of ~20% over land and 10-15% over water. We have added citation of Remer et al. (2005) and noted potential MODIS AOD overestimation in high dust loading environments.

While the MODIS AOD is useful for a qualitative comparison of the UAE and Saudi dust plumes, the data is quite patchy and covers only a portion of the domain. We have also noted that the modeled dust plumes in the RAMS simulations are slightly displaced compared to the corresponding high AOD plumes in the MODIS overpasses. These factors are prohibitive towards producing a meaningful quantitative comparison. However, visual qualitative comparisons reveal that the RAMS Ginoux and Walker simulations generate dust plumes in the region of the observed plumes. Further, the modeled plumes have AODs in the 1.5-2.5 range across the bulk of the plumes, which is very similar to the range of AOD seen in the MODIS data. While the MODIS data may have uncertainties up to 20% over land, the retrieved high AOD values are co-located with dense plumes seen in the visible imagery in Figure 4 and denote these plumes as being substantial dust events. As such, this event is worth examining in the model with respect to the potential variability in radiative effects due to different specification of dust erodible fraction.

In addition, we have interpolated the MODIS pixels to the location of the Mezaira AERONET site and added these point observations to the MODIS AOD figure. The interpolated MODIS AOD values from both overpasses are lower than the AERONET values, but are still indicative of a substantial dust event. As we note in the manuscript, the MODIS data is being interpolated to a point location in an area with a tight gradient in AOD and in the vicinity of missing pixels. As such, we suspect the interpolation tends to under-represent the high AOD at the indicated times compared to AERONET.

2. A large underestimation is seen between model and AERONET AOD. What could be the reason for this? It will be nice if the authors could provide a quantitative validation, including bias and normalized mean error. How much is the uncertainty in AERONET AOD for regions predominant with dust? I suggest strengthening this Section by providing information from any available literature study as well. One of such studies, I recently found is by Kokkalis et al.,

(2018). Long-Term Ground-Based Measurements of Aerosol Optical Depth over Kuwait City. Remote Sensing, 10, 1807; DOI:10.3390/rs1011180710.

The main point in providing the grid point comparisons of AOD is to generally demonstrate the presence of an intense dust plume in the area in both the observations and the model. As discussed in the paper, grid point comparisons, while potentially useful, can be deceptive when making comparisons in areas of tight gradients and areas where simulated features such as dust plumes are reasonably represented in the model but are slightly displaced compared to the observed location. Here, the underestimation in the model compared to AERONET is largely due to the fact that the model generates a dust plume over the UAE / Persian Gulf region that is slightly displaced to the east. Further, in the Walker simulation, there's a substantial gradient in dust AOD along the edges of the plume. As shown in the AERONET figure, a simulated in-plume grid point time series to the east of the Mezaira location does indeed reveal the passage of an intense dust plume. Such comparisons can be useful, but need to be cautiously interpreted. We have added some details from the Kokkalis et al. paper that help shed light on AODs that represent a mean background state for this region as well as dust storm AOD values.

3. Also, why "Ginoux"' is larger than the "Walker" (refer to Figure 7c)? Please include some discussion on this.

We note that figure 7c is a time series for a single grid point, so any spatial displacement between simulations can produce somewhat deceptive differences at single locations. The simulated UAE plume is displaced a bit to the east of the Mezaira location shown in the time series. As noted in the text, the Walker simulation lofts dust in more precise locations and then transports those with the wind. As such, the Walker dust plume is narrow and somewhat displaced from the Mezaira location. The Ginoux simulations have lower erodible fraction than the Walker dust locations, but the Ginoux sources cover a much larger area. As such, the Ginoux plume near Mezaira is more broadly dispersed but with a lower maximum AOD compared to the plume in the Walker simulation. We have added discussion of these differences and note that these differences need to be considered when interpreting time series of grid point comparisons.

4. How much is the difference between the simulated dust concentration from NAAPS and that from RAMS and WRF? I suggest the authors discuss this as they provide NAAPS dust concentration.

We agreed with reviewer 1 that inclusion of the NAAPS model snapshot does not offer much contribution to the paper since this is a comparison to an operational model and not real data. As such, we have removed the NAAPS figure panel and discussion from the paper.

5. How much is the expected uncertainty in your model values for radiative impacts?

There is not a general uncertainty that can be assigned to the radiation parameterization in the model. The RAMS radiation model physics predicts the radiative fluxes based on its radiative transfer equations that consider the presence of aerosols for this simulated event (Harrington 1997; Stokowski 2005).

6. I suggest comparing the radiative implications, such as radiative cooling/heating during

daytime and nighttime with observational data.

Observations of vertical profiles of radiative cooling/heating rates in and out of the dust plumes are not available. However, Stokowski (2005) demonstrated that RAMS is able to reasonably represent radiative heating associated with dust layers. Further, we have added discussion regarding the dust-induced changes in radiative fluxes and radiative heating/cooling and compared the RAMS simulated trends to those in Slingo et al. (2006) and Marsham et al. (2016). Both our results and those in the cited papers reveal a shortwave cooling trend at the surface due to dust as well as a counter balancing increase in radiative heating within the surface based dust layer. Both our results and the cited papers address the increase in radiative heating rates with respect to changes in the radiative flux divergence associated with attenuation of shortwave radiation by dense dust layers.

7. Refer to Figure 10f: Is this for Total LW fluxes? Or for total radiative fluxes (SW+LW)? Please check.

Figure 10 displays the mean profiles at night. As such, there are no shortwave contributions and only longwave fluxes are to be considered.