Reply to Reviewer 3

Interactive comment on "Development of adynamic dust-source map for NMME-DREAM v1.0 model based on MODIS NDVI over the ArabianPeninsula" by Stavros Solomos et al.

Anonymous Referee #3
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Review for "Development of a dynamic dust-source map for NMME-DREAM v1.0 model based on MODIS 1 NDVI over the Arabian Peninsula" by Stavros et al.

The authors developed a dynamic dust source map based on MODIS Normalized DigitalVegetation Index (NDVI) for the dust emission scheme in the NMME-DREAM v1.0 model over the Arabian Peninsula. Two groups of simulations are conducted for 2016,one with the dynamic source map (NDVI_run) and the other with the default static source map (CTRL_run). It was found that when using the dynamic dust source thesimulated AOD biases are reduced for dust episodes (i.e., when AOD>1) in comparisonwith the simulation using default setting. This paper explored the influence of the seasonal variation of vegetation coverage on dust emission scheme, which is a veryinteresting and important topic, and tested their methods over one major dust sourceregions, Arabian Peninsula. However, the overall presentation needs some improvement, some details need further clarification, and I also have some concerns about the methodology. My comments are listed below.
[REPLY] We thank the reviewer for the careful revision and useful comments. Indeed the seasonal variation of dust source efficiency is an important topic. In our study we focus to present an alternative method for dust source classification in the well-established DREAM dust model that will allow the system to incorporate the updated satellite NDVI for describing dust emissions. Specific replies to the reviewer's comments follow below.

Major comments:
1. In the introduction part when reviewing previous studies of dust source map, I think it is important to briefly introduce Ginoux et al. (2001), who determined dust source mainly based on topographic depressions. As mentioned in the later part of the paper,this is also the default setting used in the NMME-DREAM model. It is also informativeto explain what's new in the method used here compared with previous studies thatalso used NDVI to develop dust source map in the introduction section. And similarly, in the result section, it is better to discuss current results within the context of previouswork that also compared static dust source map with NDVI based source map in thisregion.
[REPLY] We have extended the corresponding sections in the revised manuscript by adding the following sentences in the introduction, methodology, summary and discussion sections:
Introduction: "The main differences in our approach compared to the previous studies referenced above, is that we use a very high resolution NDVI product (500×500 m) in a regional modeling domain (e.g. Kim et al., 2013 used an 8×8 Km NDVI dataset extrapolated to 1°x1° global modeling domain) and our study is not limited to specific test cases (like for example Vukovic et al., 2014 and Solomos et al., 2017), but covers an extended time period, as presented below."

Methodology: “The global mapping of dust sources in Ginoux et al.,(2001) is determined from the comparison between the elevation of surface grid points at 1°×1° resolution with the surrounding hydrological basins and with the 1°×1° AVHRR (Advanced Very High Resolution Radiometer)vegetation map (DeFries and Townshend, 1994).”

Summary and Discussion: “These findings support the previous results by Kim et al., 2013 who also showed an increase in dust emissions and a more realistic comparison with satellite observations in Saudi Arabia by the introduction of an NDVI based dynamic source mapping for GOCART model.”

2. Some details regarding the methodology need further clarification, for instance:
a) I think it will be informative to provide the equation of dust emission scheme in the NMME-DREAM model in section 1.1, so readers can see the role of the dust sourcefunction.

[REPLY]The following section has been added in the revised text: “The surface concentration is calculated using equation (11) from Nickovic et al., (2001):

$C_{sfc} = c_1 \cdot \delta \cdot u_*^2 \left[1 - \left(\frac{u_{*t}}{u_*} \right)^2 \right]$ where $c_1 = 2.4 \cdot 10^{-4} \frac{Kgr}{m^5 \sec^2}$ a tuning constant determined from model experiments, u_* and u_{*t} the friction velocity and the threshold friction velocity for dust production respectively and $\delta = a \cdot \gamma_k \cdot \beta_k$, where γ_k the ratio between the mass available for uplift and the total mass β_k the fractions of clay, silt and sand for each soil class, and a the desert mask (between 0 and 1) calculated from the Ginoux et al., (2001) dataset.”

b) How do you define “# of dust points” in your equation of “Agrid_box”?
[REPLY] The number of dust points are those that have NDVI values smaller than 0.1. A sentence has been added in the text to clarify that: “Where $^{\#\_of\_dust\_points}$ is the number of points with NDVI values smaller than 0.1.”

c) How do you define dust efficiency in line 120 and “fractional gross error” and “meanfractional bias” in Table 2?
[REPLY] By "dust efficiency" we refer to how potent is a certain area in producing dust particles by mechanical processes (wind speed).

Fractional gross error calculated for n pairs of model values (m_i) and observations (o_i) is defined as

$$FGE = 2 \left| \frac{m_\iota - o_\iota}{m_\iota + o_\iota} \right|$$

where the bar denotes the mean value (Boylan and Russell, 2006). Similarly, mean fractional bias is defined as

$$MFB = 2\frac{\overline{m_i} - \overline{o_i}}{\overline{m_i} + \overline{o_i}}$$

following(Chang and Hanna, 2004).

We have added a new section that properly defines the quantities used for model evaluation.

Chang, J. C. and Hanna, S. R.: Air quality model performance evaluation, MeteorolAtmosPhys, 87(1–3), 167–196, doi:10.1007/s00703-003-0070-7, 2004.

Boylan, J. W. and Russell, A. G.: PM and light extinction model performance metrics, goals, and criteria for three-dimensional air quality models, Atmos. Environ., 40(26), 4946–4959, doi:10.1016/j.atmosenv.2005.09.087, 2006.

d) Section 1.2 has a lot of redundant lines, e.g., lines 131-133 are the same as lines140-142, while lines 128, 135 and 143 repeated the same information.
[REPLY] Thank you for this notice. The redundant lines have been removed at the revised version.

e) According to lines 183-184, it is not clear if the simulated AOD is purely dust AOD,or it also includes the optical depth contributed by other aerosol particles?
[REPLY] The simulated AOD is purely dust AOD. The MODIS AOD may include other aerosol types.

f) Line 162 seems indicating that the model settings are different for the CTRL_run and NDVI_run? Is this true?
[REPLY] No, the only difference between the two configurations is the definition of dust sources. This line is now removed for clarity.

g) It is also important to briefly introduce the datasets used for model validation insection 1, e.g., the MODIS AOD, AERONET AOD. What are the spatial and temporal resolutions?
[REPLY] We have added a new section (1.3 in the revised manuscript) describing the validation datasets.

3. Two major differences between Fig. 2a and b are the discrepancies of dust sourcestrength over western Saudi Arabia and over Iran and western Pakistan. I think the authorsshould discuss these differences in the end of section 1.1 and also correspondinglyin the result section. It seems to me that the NDVI source map overestimatesthe dust source strength over western Saudi Arabia and consequently led to too muchAOD in this region in Fig. 3b.
[REPLY] The following lines have been added in the revised text:
“The two dust source patterns present remarkable difference especially over the western Saudi Arabia and over Iran and Pakistan where the NDVI classification results in stronger emissions.”
“The DREAM-NDVI AOD is also higher than MODIS AOD over western Saudi Arabia indicating a possible overprediction of dust sources at this area.”

4. Section 2.1 discusses dust transport by atmospheric circulation in August 2006.First of all, it is not clear to me whether information presented here is based on modelsimulation or reanalysis or observational data. Please clarify. On the other hand, thoseweekly variations of surface winds and dust transport may not necessarily be revealedin the monthly AOD map in Fig. 3. I'd suggest either adding figures of weekly variationsof wind and AOD in this section or adding monthly surface wind vectors in Fig. 3 todiscuss how winds affect AOD pattern.

[REPLY] We have introduced a new plot (Figure 3 in the revised version) that shows the average modeled wind speed and vectors for August 2006 in order to facilitate the corresponding discussion.

5. As you mentioned in lines 233-236, NDVI mask do not have much seasonalvariations in permanent deserts, but may be important in those semi-arid regions, asalso pointed by Kim et al. (2013). I wonder if you can also plot 12-month NDVI mapin this region for 2016 to demonstrate the influences of NDVI seasonal cycle and thenyou can discuss the seasonal variations of AOD in Fig. 5 along with NDVI seasonalcycle.

[REPLY] The main purpose of our study is to provide a dynamic modeling tool for dust source definition in NMME-DREAM v1.0 model and demonstrate its capability as an alternative method. Therefore we intend to constrain our work to the description of our proposed methodology. A more in depth analysis of the seasonal dust source variability of at the area would require a longer study period and will be the scope of a forthcoming study.

6. The overall magnitude of AOD in the control run is quite low but does seem to haverelatively higher values over the eastern Arabian Peninsula, which is consistent with thepattern of MODIS AOD. I wonder if you tried to tune the model in the CTRL simulation to increase the overall magnitude of dust emission and then compare the pattern andseasonal cycle of AOD with the NDVI_run.

[REPLY] The default configuration is similar to the operational model setup used for example in SDS-WAS (https://sds-was.aemet.es/) and BEYONDhttp://beyond-eocenter.eu/dusthub/, which is tuned towards stations at Africa, Asia and Europe. It is also important to notice that our proposed method is not a simple homogeneous tuning factor but an overall different treatment of dust source definitions.

7. Kim et al. (2013) combined both the topographic depression-based dust source andNDVI seasonal masking for dust source map. I wonder if you can combine the dynamicsource developed here with the default Ginoux et al. (2001) static source, and see ifthe model performance is further improved. I think those high AOD over western SaudiArabia probably will be largely reduced.

[REPLY] We agree with the reviewer that finally a combined static and dynamic approach might be a solution for operational setups. However, we selected to perform two totally independent runs in order to clearly demonstrate the use of dynamic NDVI sources as an alternative method

to the static approach for DREAM model without incorporating a vegetation map. We believe that in this way the advances and deficiencies of our development are more evident.

8. Here only modeled AOD in the two simulations are compared. I wonder if you also see any improvement in other aspects of dust life cycle such as surface dust concentration, vertical distribution, and deposition.
[REPLY] We focused on AOD for the verification since AOD observations are more regular, available and reliable than observations of profiles, surface concentrations and deposition.

Minor points:
1. Line 28, add "e.g.," before "Torge et al., 2011"
[REPLY] Done.

2. Line 31, add space between "precipitation" and "processes". Please fix all similaroccurrences.
[REPLY] Done.

3. Line 45, I don't think there is any "feedbacks" on "human health", please considerreorganizing the sentence.
[REPLY] Indeed, thank you. We have replaced "feedbacks" with "effects".

4. Line 63, please add brackets for "2013", and fix all similar occurrences.
[REPLY]Done, thank you.

5. Line 79, I think the original dust source function developed by Ginoux et al. (2001) did not use "Olson World Ecosystems dataset". Can you explain a bit more here?
[REPLY] The reviewer is correct. We have corrected this sentence in the revised text.

6. Line 109, you may want to add a line or two to explain why NDVI of 0.1 is selected instead of 0.15 as used by Kim et al. (2013).
[REPLY] Indeed it is not easy to define a "best estimate" threshold for all satellite NDVI sensors worldwide. A choice of 0.15 may be more representative on a global base as used by Kim et al. (2013) for AVHRR. Here we adopted the 0.1 threshold based also on previous studies at the area (Solomos et al., 2017) since due to the bareness of the specific modeling domain a higher value could overestimate the dust sources. This discussion is now added in the revised version.

7. Lines 200-201, not clear. Did you use Ångström exponent to mask AOD? In thatcase, the masked AOD may contain large particles such as dust and sea salt.
[REPLY] Yes this does not exclude sea salt but the contribution of marine particles to the total AOD is limited.

8. Fig. 3, it is better to mask out AOD outside the model domain in Fig. 3c for an easy comparison among the three plots.

[REPLY]Done.

9. Please clarify in Table 1 caption that this is for annual mean. And for correlation, do you use monthly data? Can you also mark whether the correlation coefficients are statistically significant?
[REPLY]Done. For correlation we use the daily AERONET data.

10. Table 2, are monthly or daily data used for correlation? Please add significance test as well.
[REPLY] We use individual AERONET measurements. The model retrievals are interpolated in time to match the AERONET measurement time. This is now stated more clearly in the revised text. To highlight the significance of correlation, in Table 2 we indicate with bold font all coefficients with p value < 0.01.

11. Fig. 5, are the time series calculated from single AERONET site (which one?) oraveraged over four stations on the Arabian Peninsula?
[REPLY]Fig.5 is averaged from the four Arabian stations. This is now more clearly stated in the text.

References:
Ginoux, P., Chin, M., Tegen, I., Prospero, J. M., Holben, B., Dubovik, O., & Lin, S.-J., Sources and distributions of dust aerosols simulated with the GOCART model. J.Geophys. Res., 106(D17), 20, 255–20, 273, https://doi.org/10.1029/2000JD000053,2001
Kim, D., M. Chin, H. Bian, Q. Tan, M. E. Brown, T. Zheng, R. You, T. Diehl, P. Ginoux,and T. Kucsera, The effect of the dynamic surface bareness on dust sourcefunction, emission, and distribution, J. Geophys. Res. Atmos., 118, 871–886, doi:10.1029/2012JD017907, 2013.