

Reply to the reviewer 2 comments

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Overall recommendation: Accept subject to minor revision

Rationale: The dust source map is one of the key aspects of the parameterization of the dust processes into NWP models. One of the biggest problems in the definition of sources is that soil conditions for dust emission change over time, cyclically through- out the year and with much less predictable inter-annual variations. Therefore, the introduction of dynamic dust source maps, based on satellite remote sensing products, seems a necessary step forward. The authors describe the implementation of a map of this type and show that with it the model considerably improves its performance.

[REPLY] We would like to thank the reviewer for his comments and suggestions. The replies to the specific comments follow:

Comments for authors:

Introduction. You should mention here previous attempts to scale the dust emissions by satellite NDVI that you mention in Section 3 (Summary and Discussion). You should emphasize the difference of your approach (if there is any).

[REPLY] We have added extended relevant sections in the revised version:

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°×1° 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.”

Page 1, line 7: The expression ‘The new modeling system’ seems excessive, when you only change the dust source map.

[REPLY] The sentence has been changed to read: “The updated modeling system.”

Page 1, line 7: “. . . is tested for the analysis of dust particles dispersion...”. I assume that the model simulates emission and deposition, not only dispersion. Moreover, the new map influences dust emission. So, why do you write you analyse dispersion?

[REPLY] The model simulated both emission and deposition and our development actually changes only the emission of dust. The sentence has been changed to read: “. . . is tested for dust emission capabilities...” in order for that to be clear.

page 1, line 13: “The modeled AOD bias is improved from -0.140 to 0.083”. It is not necessarily an improvement, since you compare dust AOD with total AOD. A positive bias is always bad news, whereas a bias of -0.14 may be acceptable. Going from -0.933 to -0.424 that does seem an improvement.

[REPLY] The reviewer raises an interesting issue. Seeing as absolute numbers a bias of 0.083 is better than -0.140, which is what we write in the text. However, as the reviewer states, an overestimation is not something we want when evaluating dust production and transport. However in more severe cases ($AOD > 1$) the model performs better. We believe that this issue could be resolved by increasing the resolution of the model domain, thus giving a more detailed representation of the dust source areas, something that our methodology allows us to do, since the resolution of NDVI product is already at 500×500 m.

Page 1, line 27: Some spaces between words are missed: ‘studies. Dust’ in page 1, line 27; ‘(CCN) and’ or ‘precipitation processes’ in page 1 line 31 and so on. Please, check it.

[REPLY] Corrected. Also the whole manuscript is revised and other instances have been corrected. Also some double spaces have also been corrected.

Page 2 line 54: define ‘SSib’

[REPLY] SSib stands for simplified simple biosphere. This has been added to the text along with its reference: Xue et al. 1991

Page 2 line 69. I would not say that the Arabian Peninsula is a good example of heterogeneous region.

[REPLY] We wanted to emphasize the use of the Arabian Peninsula as our area of interest, as it is a more heterogeneous region than the Saharan Desert, which could be used as a test area for our methodology. Of course there are more heterogeneous areas that it could potentially be tested, but the Arabian Peninsula is the second biggest desert area of the world and since we wanted a mix of desert size and soil heterogeneity, we deemed it proper for our work. A small comment has been added to the text.

Section 1.1. Although there are references on it, I would include a short paragraph describing the main aspects of the dust model (emission, deposition schemes, whether or not there is radiative feedback, ...)

[REPLY] Section 1.1 has been updated and new references have been added to include additional information about the model processes following the reviewer's suggestion.

Page 3 line 93: I would suggest 'nonlinear partial differential equation' instead of 'partial differential nonlinear equation'

[REPLY] We agree. It has been changed in the manuscript accordingly.

Page 3 line 111: 'The NDVI dataset is at finer resolution than the model grid'. Which is the resolution?

[REPLY] The resolution of the NDVI dataset is 500×500 m. This has been added to the sentence.

Page 3 line 117: 'we have applied a limit to dust efficiency over high mountain'. I think it would be worth explaining it a little. A limit on a threshold altitude?

[REPLY] The following paragraph has been added in the revised version: "In order to exclude such unrealistic emissions from non-soil bare areas or snow-covered areas we have applied a limit of zero dust production above 2500 m over the entire domain. This simple approach has been selected in order to keep our straightforward NDVI mapping independent of vegetation and soil information. The threshold value of 2500 m does not suppress the emissions from lowlands and hillsides (e.g. the coastal areas of Hejaz Mountains in Red Sea that have been identified as hot dust spots by Anisimov et al., 2017)."

Page 3 line 124 & page 4 line 152: In other parts of the text, you mention that the NDVI product is a 16-day average. Here, you present it as a monthly product. Please, clarify.

[REPLY] Corrected. The product presented here is the 16 day average from 1st to 16th of August 2016. It has been change in the revised text.

Page 4 line 137. Please, check the ratio's denominator in the equation below.

[REPLY] Corrected. It now reads $X_{nir} + X_{red}$

Page 4 line 138. 'top of the atmosphere reflectance'. Shouldn't be surface reflectance (measured from the top of the atmosphere)?

[REPLY]. This is actually surface reflectance as would be measured at ground level (i.e. corrected for atmospheric effects). This is now stated more clearly in the revised text.

Page 4 line 144: 'The high resolution masks was used...'. I don't understand what these masks are. I suppose you use the equation of line 113. In any case, '... masks were used...'

[REPLY] Correct. We change this to high resolution dataset in order to be clear.

Page 5 line 175: 'Arabian Gulf'. I don't want to participate in a naming dispute, but in most international treaties, documents and maps, this body of water is known by the name of Persian Gulf.

[REPLY] We changed this phrase to: "over the Red Sea and Gulf regions"

Page 6 line 184: I suppose you should comment on the deficiencies of the monthly average of MODIS AOD. I mean that the daily datasets do not cover, far from it, the entire territory due to the presence of clouds, excessive zenithal angle, etc.

[Reply] This is correct. We have added a description and reference to better highlight the limitations of the 16-day NDVI product, especially focusing on the compositing difficulties: "The 16-day composite is calculated by ingesting two 8-day composite surface reflectance granules, while the procedure takes into account pixel quality, presence of clouds, and viewing geometry. This procedure can lead to spatial discontinuities, as it is possible that data from different days are used for adjacent pixels, each representing different measurement conditions. If a pixels has with no useful measurements during the 16-day period, historic data are used as fill values (Didan et al., 2015)."

Page 6 line 195: 'miss-classification of Iran and Pakistan grid points'. The overestimation along the Iran-Pakistan coastline is very striking. Can you guess a possible cause of this miss-classification here?

[REPLY] Indeed the overestimation is an issue at that area because of the complexity of the terrain in that area, where barren land changes abruptly to desert and vice versa. As stated in the text this is probably "due to a possible miss-classification of Iran and Pakistan grid points as effective dust sources thus favoring unrealistic southeasterly transport towards the Gulf of Oman."

Page 6 line 200: ‘measurements of AOD?. Please, replace measurements with retrievals.

[REPLY] Corrected according to reviewer’s comment

Section 2.2: In the first paragraph you compare monthly averages of MODIS AOD with monthly averages of simulations. You should explain what you compare in the second paragraph: monthly averages, timeseries with individual retrievals, daily averages,

[REPLY] In the second paragraph of section 2.2 we compare monthly AOD values. A sentence has been added for clarity: “The first step is to examine how our methodology compares against the monthly average AOD in our study area. Therefore the monthly average AOD values produced from our two simulations (NDVI_run and CTRL_run) are compared.”

Page 7 line 218. Please, re-phrase the sentence starting with ‘The bias reverse is evident ...’

[REPLY] Rephrased. The sentence now reads: “Both cases show an improvement in the bias values over the control simulations. When we consider $AOD > 1$ the NDVI_run still underestimates the observed values, but with a lower RMSE (0.586 versus 0.983 of the CTRL_run).”

Page 7 line 236.the sentence starting with ‘These may include bog, marsh, ...’ should be revised. Probably you refer to dried or dessicated bog, marshes,

[REPLY] Revised according to the reviewer’s comment.

Different formats are used for citations. Please, check it.

[REPLY] The citations have all been reformatted according to the guidelines of the Journal