Review of "Investigation of observed dust trends over the Middle East region in NASA GEOS Earth system model simulations" by Adriana Rocha-Lima et al.

General comments:

This paper examines the capability of the NASA GEOS model to reproduce the observed positive AOD trend over the Middle East during 2003–2012. It is found that the model output without aerosol assimilation (MERRA-2 GMI Replay) only shows a weakly positive trend over southern Saudi Arabia and eastern Oman, while the simulation with aerosol assimilation (MERRA-2) largely captures the spatial pattern of the AOD trend shown in satellite retrievals, although in a weaker magnitude and the hot spots over the central to eastern Fertile Crescent region are missing. A sensitivity test that allows dust emissions over the regions with a strong decreasing trend in NDVI increases AOD in western Syria and Iraq and downwind regions over southeastern Saudi Arabia and Oman, largely reducing the discrepancies between model output and MODIS AOD. This suggested that vegetation reduction in the Fertile Crescent region contributes to the observed positive trend of AOD. While the findings advance the understanding of the model's capability to capture long-term dust trends in the Middle East and the role of vegetation in dust trends in the region, some details about simulation settings and the selection of analyzed region and months need further clarification.

Specific comments/suggestions:

1. Section 1.1 reviews previous observational and modeling studies of AOD over the Middle East. However, it is not very clear why the study focuses on 2003–2012 instead of a longer period, i.e., 2003 to the present. Are there any trends in AOD from 2013 to 2022 (or 2023)? I think it's informative to place the current study of the positive trend in AOD in the context of long-term variations in AOD in the region. For instance, previous studies (e.g., Notaro et al. 2015) related AOD variability in the Fertile Crescent to low-frequency variations of the Pacific Decadal Oscillation. Is this positive trend of AOD during 2003–2012 part of long-term decadal variations in AOD in the Middle East?

2. Section 2, it would be more informative to add some comparisons with previous studies when discussing findings in Sections 2-3.

3. It's helpful to add a data section to briefly introduce the satellite products (e.g., MODIS and MISR AOD, MODIS NDVI) used in the study.

4. The dust source function in the GOCART module is determined by both topographical depression and surface bareness so dust aerosols are emitted from bare ground or sparsely vegetated regions (Kim et al. 2013). I wonder if an NDVI threshold/mask is applied to the source map shown in Fig. 7a in the baseline simulation as well. And if so, is it a climatological mean or time-varying NDVI?

5. The setting of the sensitivity test (lines 201-206) needs a bit more clarification. For instance, a region with a strong decreasing trend in NDVI is selected (i.e., $<-0.0025\ yr^{-1}$) to allow dust emissions. However, it is not clear what the absolute value of NDVI is in the selected region and whether NDVI in the region is low (i.e., sparsely vegetated region or bare ground) all the time during the simulation. It is also not clear how long the simulation is conducted.

As shown in Fig. 8, AOD in the masked area is higher in the dust-enhanced case than in the baseline case, which indicates that dust emissions in the same area are in fact suppressed in the baseline simulation. Is this correct?

6. It is not fully clear why the comparisons between model results and MODIS focus on JJA. Is it the time when NDVI shows the strongest decreasing trend or when MODIS AOD shows the greatest trend? Since the earlier discussion uses monthly data or annual values, it is better to add some discussion to justify the selection.

7. Fig. 4 suggested that both soil moisture and surface wind speeds play little role in the increasing trend of AOD in the model. It should be noted both variables from MERRA-2 or MERRA-2 GMI Replay may contain errors from the model thus the trends revealed in Fig. 4 have uncertainties. For instance, surface winds in the reanalysis may be underestimated (e.g., Largeron et al. 2015; Evan et al. 2018). It would be interesting to compare the trends found there with studies using ground observations.

8. While many previous studies of AOD or dust trends are discussed in section 1.1, a few recent papers also examined aerosol trends in the Middle East, e.g., Chen et al. 2019; Song et al. 2021; Xi 2021; Sabetghadam et al. 2021; Liu et al. 2023.

9. Line 93, “constrained by the MERRA-2 Reanalysis”, can you please provide more details about the constraints? Are MERRA-2 meteorological fields prescribed?

10. Line 97, “prescribed soil”, from what dataset?

11. Lines 100-103, please provide temporal resolution of the datasets.

12. Line 189, please add a couple of lines to introduce the FluxSat GPP data.

13. line 213, are the results from the optimum-matching run shown in Fig. 8?

14. Fig. 8, in addition to comparing AOD patterns, have you examined the trend of AOD from the dust-enhanced case? Are the simulated magnitude and pattern more consistent with MODIS than the baseline simulation?

15. Line 227, “use the same wind fields”, Fig. 4 shows wind fields in the two datasets are slightly different from each other.

16. Line 245, “it has also been linked to deforestation”, the reduction in NDVI could be due to both droughts and deforestation.

Technical corrections

Fig. 1 caption, please explain the red shading in 1(b)

Fig. 4, do white contours denote areas with a p-value less than 0.05? If so, please add the info to the figure caption. It’s somewhat redundant to show maps of p-values if the contours of significant areas are overlayed on the regression slopes.

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