**Responses to reviewer comments**

Dear reviewer:

Many thanks for the constructive comments. We have carefully considered and addressed each comment in blue with the original comments in *italics*. Changes are highlighted in yellow in the revised manuscript.

Best regards,
Yahui Che on behalf of all authors
9-December-2023

*To reveal the temporal and spatial features of dust activity in Australia, the authors developed a new product of MODIS and MERRA-2 combined (M&M) DAOD. They further evaluated tis MODIS-MERRA DAOD by using multiple measurements. Then the authors presented many results on the spatial variations and seasonal features in dust activity.*

*Overall, this is a well-conducted study and the authors show some interesting results. The developed combined DAOD could be very helpful. However, I believe this manuscript can be improved by doing more in-depth analysis on the long-term trend of dust activity. Please find my comments below.*

Thanks for the positive comment. The comments below have been addressed and revisions have been made in the revised manuscript.

*My major concern is about the analysis on temporal variations of Australia dust activity. The authors mainly talked about long-term trends of dust budget from 1980 to 2020, but in fact a further discussion on the key factors driving these trends is needed. In addition, Fig.12 only shows mean dust emission over 1982-2019; I think a spatial trend for dust emission should be given which might be linked to variations in rainfall and land cover.*

A spatial trend analysis has been added:

"As dust emissions are primarily determined by soil moisture content and surface wind speed (Ginoux et al., 2001), rainfall is strongly correlated with dust emissions (Figures 12a and b). Areas of dust emission, such as the center of the Lake Eyre Basin and the Nullarbor Plain, are typically associated with low rainfall, especially below 150mm/yr. The Mann-Kendall (MK) tests conducted on annual dust emission and rainfall data from 1980 to 2020 further highlight the substantial inhibitory impact of rainfall on dust emissions. A decreasing trend of dust emission occurred over the past 40 years with increased rainfall for almost all regions, especially in southwest of WA ((figure 12e). Northern Australia commonly shows an increasing trend of rainfall, while dust emissions remained essentially unchanged. This is because the highly vegetated surface in Northern Australia rarely emits dust particles. Conversely, with significant decreasing rainfall ($p < 0.05$), the southwest of QLD, as a part of the Lake Eyre Basin, shows an increasing trend of dust emissions. Nevertheless, the impact of photosynthetically active vegetation on dust emissions was ignored in Ginoux's dust emission scheme (figure 12f), potentially resulting in uncertainties in dust emission estimates. Despite sharing a similar spatial pattern with rainfall trends, NDVI trends show an opposite trend to dust emissions in most of the Lake Eyre Basin. This indicates that the decreasing trend of photosynthetically active vegetation cover also contributes to the increasing trend of dust emissions in the southwest of QLD. It is essential to acknowledge and consider this factor in dust emission estimations.

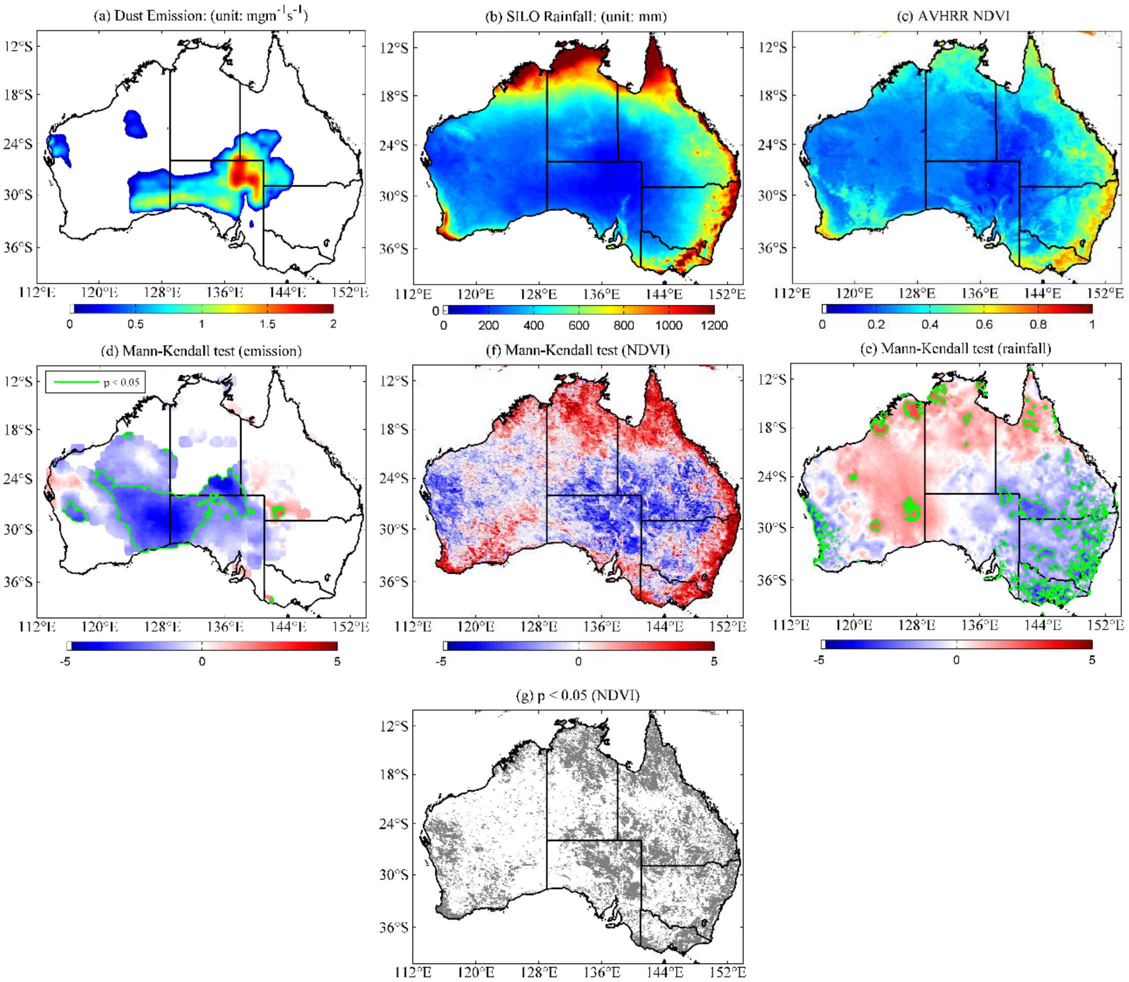


**Figure 12: Mean annual MERRA-2 dust emission (a), SILO mean annual rainfall (b), and (c) AVHRR NDVI, and (d) Mann-Kendall (MK) test for annual dust emission, (e) for annual rainfall (f) for annual NDVI from 1982 to 2019. Positives and negatives represent an increasing and decreasing trend, respectively. A p-value < 0.05 for MK test is shown with green lines for dust emission (d) and rainfall (e) and gray colors for NDVI in (g).”** (Lines 636-658, Pages 28-29).

*Fig.3 looks like that the MODIS-MERRA DAOD is not in a good agreement with AERONET AOD. So I am not convinced by this validation.*

The EE (expected envelope) lines are often used to indicate agreement between satellite AOD and ground-based data (Chu et al., 2002; https://doi.org/10.1029/2001GL013205). The EE for the M&M DAOD is only $\pm(0.016+0.15\tau_{\mathrm{Aero}})$, which is much lower than that for MODIS DB or MERRA-2 DAOD ($\pm(0.016+0.15\tau_{\mathrm{Aero}})$ ) in Australia. Another example is that the EE for MODIS DB data on a global scale is $\pm(0.05+0.20)$ while they have a strong agreement, with an r value of 0.9 (Sayer et al., 2019; https://doi.org/10.1029/2018JD029598). These different EEs are not contradictory, because AOD ranges from 0.0 to more than 3 on a global scale while the maximum DAOD in this validation is around 0.1 for Australia. As a result, under low aerosol conditions, satellite data tend to have a small absolute error, with weaker correlation; however, it does not mean their agreement is not good.

*L306: what's the meaning of expected envelope and how is it determined?*

The EE (expected envelope) lines, expressed as $\pm(a+b\tau_A)$, are typically used to indicate the accuracy of MODIS AOD datasets where a and b were determined to have these two lines contain 68% of data points (Levy et al., 2010; doi:10.5194/acp-10-10399-2010 ).

Its definition has been added:

"These studies show that there is a high probability of data points (MODIS DB and AERONET) within the expected envelope (EE) lines, which are defined with two lines (±(0.03+0.15τ)) containing approximately 68% of data points (Che et al., 2022)." (Lines 277-278, Page 11)

*L463: please replace "PM" by "PM10"*

"PM" has been replaced with "PM10"

"Figure 9: Seasonal MERRA-2 near-surface dust concentration in (a) Dec-Feb, (d) Mar-May, (g) Jun-Jul, and (j) Sep-Nov from 2002-2020; Seasonal MERRA-2 PM10 in (b) Dec-Feb, (e) Mar-May, (h) Jun-Jul, and (k) Sep-Nov from 2002-2020; and the ratio of MERRA-2 near-surface concentration to MERRA-2 PM10 in (c) Dec-Feb, (f) Mar-May, (i) Jun-Jul, and (l) Sep-Nov from 2002-2020." (Lines 492, Page 22)

*L513: what's the reason of an increasing dust deposition after 2010? How about the trend in different seasons?*

A possible reason for the increasing trend of dust deposition has been added:

"The post-2010 trend of dust deposition is likely caused by surface wind speed. Annual dust deposition shows a strong correlation with the silt particle fraction (figure 13a) for the period from 1980-2010 (blue) and post-2010 (green). Large particles have a higher settling velocity. As more than 86% of dust was deposited on the land, and dust emission and import remained largely unchanged since 2000. A higher fraction of silt particles indicates that deposited material is made up of mostly silt particles. Nevertheless, as the surface wind speed is a key factor in dust emission estimation, an increasing surface wind speed would entrain more coarse dust particles, leading to more dust deposition on the land, as indicated by an $r^2$ value of 0.44 between dust deposition with surface wind speed (figure 13b). Additionally,

Fig. 14 shows seasonal variations in the amount of dust deposition in mainland Australia with the maximum deposition occurring in summer (Dec-Feb), and the minimum in autumn (Sep-Nov). It is clear from Fig. 14 that the minimum deposition has increased from less than 1 Mt in 2011 to more than 3 Mt over the past several years (2017-2020), while the peak deposition has not changed significantly over the 11 years (Fig. 14).

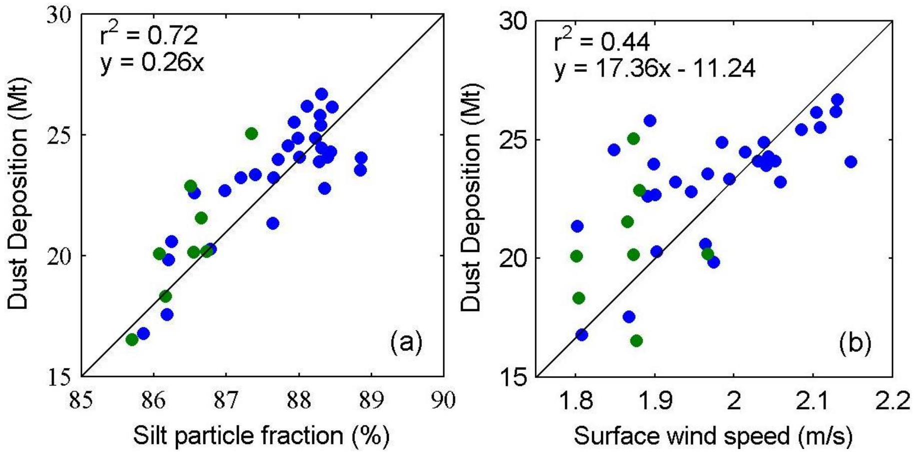


**Figure 13: Relationships between annual dust deposition and (a) silt particle fraction, and (b) surface wind speed 1980-2016. Green points represent data since 2010; Indicators in each panel are calculated using all data points.**

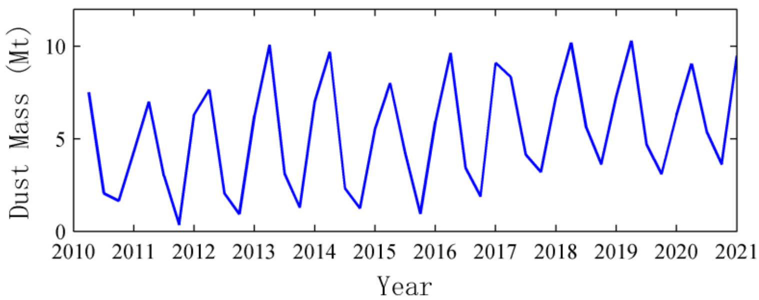


**Figure 14: Seasonal dust deposition on mainland Australia since 2000**

” (Lines 661-676, Page 29-30)