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Title: Impacts of long-range transported mineral dust on summertime convective cloud and precipitation: a case study over the Taiwan region

Authors: Yanda Zhang et al. Response to referee comment #2

We sincerely thank the referee for the detailed reviews and constructive comments which help to improve the manuscript. Below we respond to the comments in detail (*Referee's comments are in Italic*). The manuscript has been revised accordingly.

In this study, the authors investigate the impact of dust aerosols on convective clouds in summertime over the mountain ranges in Taiwan. The selected case with heavy rainfall occurred in July 2006. They used the global WRF model with two different microphysics schemes, the spectral-bin (SBM) and the bulk Morrison (Morr2) scheme. They performed model simulations with and without a coupling of dust to the immersion freezing process using both microphysics schemes to analyze dust effects on convective clouds. The Morr2 scheme uses a saturation adjustment approach, which is replaced in one model simulation by explicit calculations of evaporation and condensation of cloud droplets. The model results are evaluated with observations and the MERRA-2 reanalysis. I thank the authors for this nice article and recommend it for publication after minor revisions. Please find some general minor comments below and some detailed comments and suggested corrections in the commented manuscript.

Sincere thanks to the reviewer for the comments and suggestions. Please find the point-by-point responses below, and the changes to the manuscript are given by the line numbers in the revised draft with track changes.

Comments:

1. *Introduction: You should mention somewhere the typical lifetime of dust particles.*

Thanks for the comment. The dust aerosol lifetime related content and references are added in the Introduction and related papers are cited (lines 25–26).

2. *L45: You mentioned that dust in the mountain ranges of Taiwan originates from different source regions. You could mention that the chemical composition of dust differs for different source regions.*

Thanks for the suggestion. Previous studies use multiple methods to study the sources of dust over the Taiwan region, including backward trajectory analyses, satellite observation, site measurement, model simulation, and, as mentioned, the chemical composition of dust. The related description is added (lines 56–58)

3. *L65: Reference for long-range transport needed.*

As introduced in this paper, previous studies indicate that the atmospheric dust over Taiwan is dominated by the long-range transport of dust and the local dust source is neglectable in most cases. Also, there is no local dust emission over the Taiwan area in the GEOS-Chem model. Thus, we think the dust event on July 8, 2006, is a long-range transport case. We cannot find related references for long-range transport in this specific case. We have slightly modified the text to avoid confusion.

4. *L76: Nd is usually used for the cloud droplet number concentration and it is a bit*

confusing to use this here for the dust concentration.

Thanks for the comments. As this study is closely related to our previous study of the analysis of dust-cloud-precipitation interactions over the Taiwan region (Zhang et al., 2020), we use "N_d" to represent the dust number concentration to keep the two papers consistent. We will use other abbreviations to avoid confusing in our future work.

5. *L78: You mean the Nd output are daily and hourly means, right?*

Yes. The daily mean N_d is calculated by averaging the hourly model output, and related adjustments are made (line 87).

6. *L82: Are there any conclusions about the model performance of the GEOS-Chem model which you can draw from previous studies?*

Thanks for the suggestion. In our previous studies on the dust properties over the Taiwan region (Zhang et al., 2019; Zhang et al., 2020a), the comparison between the satellite and surface site observations indicates that the GEOS-Chem model can reasonably capture the occurrence of dust events and variations of dust concentration. The corresponding figure and text are updated in the revision (lines 93–94)

7. *L137: The long-term mean is for the entire July 2006, right?*

Sorry for the unclear statement in the manuscript. Here the "long-term mean" is for all the clean days (with $N_d <$ the 50th percentile) in July over the last 30 years (1989-2018). An adjustment has been made to clarify this (line 155).

8. *L148: Why do you consider only fine dust PM2.5?*

This is a good question.

Here we use the PM2.5 dust mass mixing ratio to quantitively evaluated the GEOS-Chem dust simulation, this is because previous studies suggest that the mass and number concentrations of dust aerosol are generally controlled by particles in coarse and fine modes, respectively (Hoffmann et al., 2008; Kaaden et al., 2009; Mahowald et al., 2014; Denjean et al., 2016). As this study concentrates more on the dust number concentration, we chose the first two bins (diameters 1.46 and 2.8 μm) of the MERRA-2 dust mass mixing ratio to qualitatively compare with the dust mass simulation (diameter from 0.5 to 2.5 μm) from GEOS-Chem-APM.

The supplement is added in the Data section to clarify this point (lines 105-110), and adjustments are made accordingly. Related references are added.

9. *L175: You mentioned the constant droplet concentration assumption in the Morr2*

scheme. How about the SBM scheme?

In the SBM microphysics scheme, the lognormal modes are used to represent the concentration, mean radius, and model width of CCN initial and boundary conditions. CCN is activated to be cloud droplets at the cloud base and in the cloud, according to the supersaturation and temperature conditions. This different treatment of cloud droplet is one of many different parameterizations between the Morr2 and SBM schemes, thus is not mentioned in the manuscript.

10. L186: Morr2-Clean and Morr2-Dusty look similar in terms of predicting a double-center in the rainfall distribution.

Thanks for the comments. In Fig.2, the simulated precipitation patterns by the Morr2-Clean and Morr2-Dusty runs do look similar. The related contents have been revised in the manuscript (lines 201–205).

11. L197: You mean the CCN activation by aerosols, since the Morr2 scheme has this constant droplet concentration, right?

Yes, the cloud droplet number concentration (CDNC) in the Morr2 is constant, and the CCN number concentration in SBM schemes is assumed and described using lognormal modes. Thus, the potential effects of CCN activation by aerosols are not considered in the Morr2 or SBM schemes in this study.

12. L200: Table 2 is missing.

Sorry for the mistake. We removed the original “Table 2” for it gave the same information as exhibited in Fig. 3. The correction is made to the draft (around line 220)

References

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Denjean, C., Cassola, F., Mazzino, A., Triquet, S., Chevaillier, S., Grand, N., Bourrianne, T., Momboisse, G., Sellegri, K., Schwarzenbock, A., Freney, E., Mallet, M., and Formenti, P.: Size distribution and optical properties of mineral dust aerosols transported in the western Mediterranean, Atmos. Chem. Phys., 16, 1081–1104, https://doi.org/10.5194/acp-16-1081-2016, 2016.

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