This manuscript reports results of WRF model simulation to quantify the spatial and temporal variability of dust emissions, dust loading, and their characteristics within the Tibetan Plateau during 2004-2006. The authors divide the main body of the Tibetan Plateau into three regions, and argue that the results of the simulations about dust activity were consistent with the reanalysis data and ground observations.

Overall, simulation of winter dust on the Tibetan Plateau is with great importance. However, this manuscript has some shortages, and some of the implications and discussions in the manuscript are not appropriate. I have a number of comments and concerns listed below, and the authors should make Major revisions of this manuscript before it can be potential published on ACPD.

[Response] Thank you very much for your suggestion. In particular, many references are provided that allows me to verify the research results and modify next steps of my research plan. We have taken all of the specific comments into account in the revised version of the manuscript. Please see the detailed response marked blue below and the changes marked red in the revised manuscript.

Main comments

1.The current definition of the Tibetan Plateau is confusing and not appropriate. In common sense, the Tibetan Plateau is the region higher than 2500 or 3000m above sea level. The western of the Sichuan Basin, the western of the Loess Plateau, the eastern of the Tarim Basin and other regions shown in Fig. 1 cannot be incorporate into the Tibetan Plateau. Please read the definition by Yao et al., 2012, Nature Climate Change (DOI: 10.1038/NCLIMATE1580) and Liu et al., 2022, Global andPlanetary Change (https://doi.org/10.1016/j.gloplacha.2022.103893).

[Response] Thank you for your comment. In this manuscript, which definition of the Tibetan Plateau we chose is that the region extends from the Pamir Plateau in the west to the Hengduan Mountains in the east, from the southern edge of the Himalayas in the south to the northern side of the Kunlun-Qilian Mountains in the north. Li Bingyuan (1987) discussed the principles and specific boundaries for determining the extent of the Tibetan Plateau in a more systematic manner, and proposed that the basic principles for determining the extent of the plateau should be based on the geomorphological features, the plateau surface and its altitude, while taking into account the integrity of the mountains. Zhang Yili

(2002) argued for the principles of determining the extent and boundaries of the Tibetan Plateau based on new research results in related fields and years of field practice, and combined with information technology methods to precisely locate and quantitatively analyze the extent and location of the boundaries of the Tibetan Plateau, then they put forward this definition of the Tibetan Plateau. (http://data.tpdc.ac.cn/zh-hans/data/61701a2b-31e5-41bf-b0a3-607c2a9bd3b3/)

Actually, the region higher than 2500 or 3000m above sea level was widely used by many scholars, but we chose the definition mentioned above because we want to cover the main body of the Tibetan Plateau as much as possible, meanwhile avoiding the influence of large drop in elevation. Besides, WRF-Chem can only provide regular rectangular areas for simulation, grid point with a resolution of 6 km is the compromise between resolution and simulated regions so that there are much more other regions were considered in simulation. Therefore, the difference of area between two definitions on this region could be ignored compared with the giant body of the Tibetan Plateau.

2.The division of the three regions on the Tibetan Plateau is crude. The authors mentioned that the resolution of WRF model was 6 km, it can be more precise for division of those three regions. The dust sources of the plateau are located in the northern part of the Qiangtang Plateau, the Yarlung Tsangpo River basin, the Namucuo and Lhasa regions, the Qaidam Basin, the source areas of the Yellow and Yangtze Rivers, and the Qinghai Lake and its surrounding areas. Therefore, Istrongly suggest the authors use Qiangtang Plateau (between the Kunlun Mountains and Gangdisi Mountains) as the western Tibetan Plateau, north of the Tanggula Mountains (roughly around 32-33 °N) as the Northern Tibetan Plateau, and south of the Gangdisi Mountains-Tanggula Mountains as the Southern Tibetan Plateau, on the basis of the definition of the Tibetan Plateau (higher than 3000m or 2500 m).

[Response] Thank you for your comment. There has been controversy over the division of the three regions on the Tibetan Plateau. The original intention in designing the experiment is that we want to ensure the remote inland in the western Tibetan Plateau is a source of sand and dust (such as Ali and its surrounding areas) and make a quantitative description of dust emissions in this area. Our team have carried out long-term aerosol investigation and observation experiments in the Ali region (Zhang et al., 2021, https://doi.org/10.1029/2020JD033286), during this time we found that Small dust events occur frequently in Ali and its surrounding areas. So when we divided regions, we tried to cover these areas and exclude surrounding deserts. As for the northern region and southern region we chose the 85 °E and 33 °N as the boundary because of the difference of temperature and precipitation. (Jiang and Wang, 2001, Jia et al., 2015).

But combined with the results of this research, the division of the three regions on the Tibetan Plateau from you could be as a good reference for the delineation of future research work areas. Thank you again.

3. The authors only provide results of three years during 2004-2006. However, a climate pattern (30 years, such as 1991-2020) can provide more confident results and reliable conclusions.

[Response] Thank you for your comment. Wang and Zhang (2006) analysed the number of days occurred with dust and sandstorm weather (including floating dust, sand, dust storms and strong dust storms) based on observations from meteorological stations. The results show that there are two main areas of high dust and sandstorm weather occurrence in Northeast Asia during spring 2006, one occurring in the Taklamakan Desert and surrounding areas in southern Xingjiang, China, and the other being probed in the arid region of southeastern Mongolia, (https://kns.cnki.net/kcms/detail/detail.aspx?dbcode=CPFD&dbname=CPFD9908&filename=ZGQX200610001000&uniplatform=NZKPT&v=AmhKSmhN9Hr4mkIG2ftYQjIhYCFvE0I3ZZDE2M8SR2XxbFxuQzrQEE90QS_Owhk16TIlsFxDV78%3d). And a dust storm was observed on 22, Jan, 2006. So we simulate the Tibetan Plateau from 2004 to 2006 to quantify the spatial and temporal variability of dust within the plateau.

Obviously, a long duration simulation is important, but short simulations are also indispensable. Results of long simulations are prone to bias, Short-time simulations do not reflect trends. The results of this short simulations proved that this way to simulate dust emissions of the Tibetan Plateau is credible. And Long-term simulation about the Tibetan Plateau dust emissions will be my next work plan.

4. The dust emission rate data on the Tibetan Plateau throughout the manuscript should be checked carefully. Previous studies reported that dust emission rate in the Taklimakan desert was about 0.38 ton/ha yr (equals to 38 g/m^2), in the Central gobi-desert is about 0.24 ton/ha yr (equals to 24 g/m^2) (see Xuan et al., 2002, Atmospheric Environment, https://doi.org/10.1016/S1352-2310(02)00585-X). In comparison, the authors report dust emission rates of about 11.00 $\times 10^7$ μg·m^{-2} (equals to 110 g/m^2) in

the west, 3.30 $\times 10^7$ µg·m^{-2} (equals to 33 g/m^2) in the south and 4.5 $\times 10^7$ (equals to 45 g/m^2) in the north during winter on the Tibetan Plateau, in this work. I am not sure whether dust emission rate on the Tibetan Plateau can be much higher than the Taklimakan desert and Go-bi desert?

[Response] Thank you for the reference that you recommended, I have carefully investigated this article and discussed the details with my co-authors. In this article, the authors use 30-year (1951–1980) climatological data and the modified US EPA empirical formulas to finish the research. The result that dust emission rate in the Taklimakan desert was about 0.38 ton/ha yr (equals to 38 g/m^2), in the Central gobi-desert is about 0.24 ton/ha yr (equals to 24 g/m2) is averaged over many years, it may have smoothed out some great values. Besides, the data between the reference and us used to simulate spanned a large time, from 1980 to 2004. And different models have various schemes of dynamic and thermal mechanism. So it is normal to see different results.

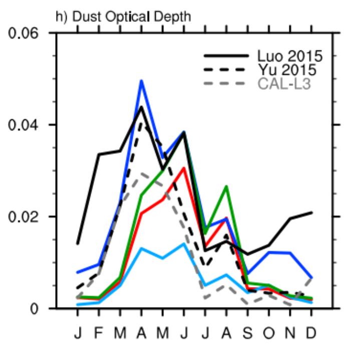
According to the latest research that the observations and simulated results showed that the QTP had a high dust emission rate, and the dust (PM10) emission intensity in the QTP during the period of 2000 to 2020 ranged from 0 to 1042 g/m^2/y with a mean value of 32.4 g/m^2/y. (Du et al., 2022, https://www.sciencedirect.com/science/article/pii/S0016706122002373). And the averaged value from our simulations is 910 g/m^2/y, So I think the result is credible.

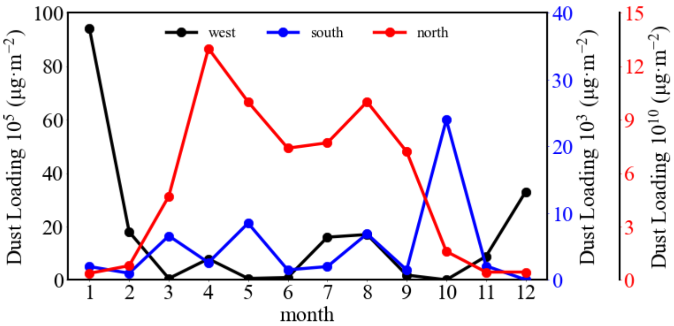
5. In the abstract, "few studies have been conducted on dust aerosols within the plateau", and Line 80-83, "there are few studies on dust within the plateau, and conclusions regarding the distribution of dust sources within the plateau, the spatial and temporal variability of dust initiation, and the contribution of dust to the air column above the TP are not clear". As far as I know, there are many studies on dust aerosols in the TP. The sentences are too absolute. For example, Liu et al., ACP 2008; Kang et al., AE 2016; Mao et al., SCIENCE CHINA Earth Sciences 2013;Mao et al., AE 2019; Yuan et al., JC 2019, etc. Mao et al., did a lot of work on dust using WRF-Chem in the TP. What are the differences between your manuscript and Mao's work? The authors should highlight your characteristics and differences relative to previous studies. In addition, please add the dynamic mechanism related to your results in the abstract.

[Response] Thank you for the references that you listed, I have investigated these articles carefully, and the text has been revised accordingly. Obviously, Mao's work has led to a number of important results and has provided much assistance in the design of the research work and validation of the results in this paper, this article also cites many of the results of his work (Mao et al., 2013, Feng et al., 2020). But they analyzed the Tibetan Plateau as a whole in their simulations and chose a coarser grid resolution.

As stated in the introduction to our article, the complex topography and sub-surface conditions make the climate very different in different regions of the TP. So the characters of dust emissions and dust loading in sub-regions of the TP are significantly different. However, setting and analyzing the Tibetan Plateau as unity in simulation only reflects northern character only, because of the high value of dust loading of northern region. There are two pictures below, left one is dust optical depth (Wu et al., 2019, https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2019JD030799), right one is dust loading of this article, they show that both the trend of dust optical depth in the Tibetan plateau and the trend of dust loading in the northern region are bimodal structure, but the trend of dust loading in the western and southern region are not. So sub-regional study of the Tibetan Plateau could be useful for future studies on the climatic effects of the Tibetan Plateau aerosols.

What's more, finer resolution can better reflect the details of the spatial distribution of dust on the Tibetan Plateau. And the abstract and introduction were modified.





"Because of the unique geographical location of the Tibetan Plateau and its important role in global climate change, aerosol variability over the plateau has been of wide interest to the academic community. Most studies have focused on the influence of external aerosols; however, a few studies have been conducted on dust aerosols within the plateau. In this study, the plateau was divided into three regions, west, south, and north based on surface vegetation and climatic characteristics, and the Weather Research and Forecasting model with Chemistry was used to simulate the Tibetan Plateau from 2004 to 2006 to quantify the spatial and temporal variability of dust within the plateau with high resolution. The dust sources of the plateau are located in the northern part of the Qiangtang

Plateau, the Yarlung Tsangpo River basin, the Namucuo and Lhasa regions, the Qaidam Basin, the source areas of the Yellow and Yangtze Rivers, and the Qinghai Lake and its surrounding areas. Owing to windy weather and arid soil conditions, the dust emissions of the three regions reached 11.00×10^7 (west), 3.30×10^7 (south) and 4.50×10^7 (north) $\mu g \cdot m^{-2}$, during winter, and remained at a low level from May to October. Although the annual variation in dust emissions was relatively consistent across the three regions, there were substantial differences in dust loading, with almost no dust present in the atmosphere in the south, a peak dust loading of 94.00×10^5 $\mu g \cdot m^{-2}$ in January in the west, and a bimodal structure in the north with peaks in April and October and a maximum value of 13.00×10^{10} $\mu g \cdot m^{-2}$, which was primarily influenced by the temperature 2 m above the ground. In summer 10% of the dust that starts in the interior of the plateau can be transported to the upper troposphere (above 8 km)."

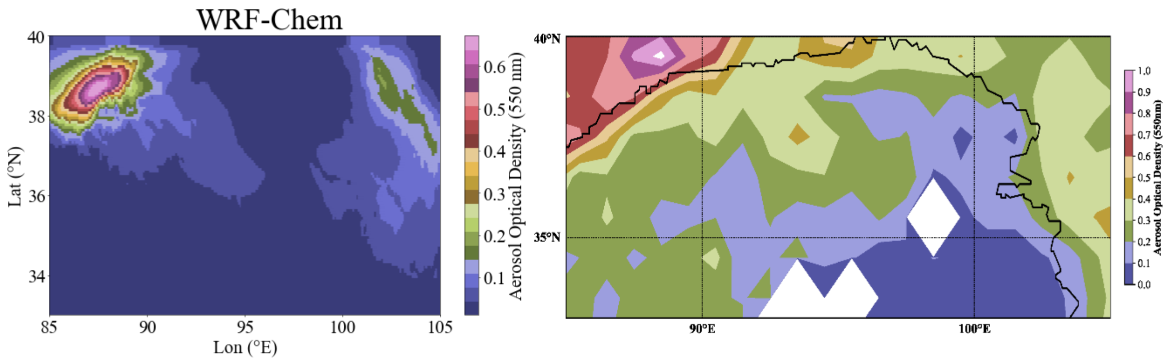
"However, the TP itself is an important source of dust, with severe desertification and many sand dunes in various regions (Fang, 2004; Li et al., 2001). Observations show that dust events on the plateau tend to occur in spring and winter, and that the dust bands tend to move northward (Han et al., 2008). Owing to the climatic sensitivity of the plateau and its influence on global climate, it is important to quantify the contribution of dust outside and within the TP to the atmosphere above the plateau. At present, there are a few studies on dust inner the plateau, and conclusions regarding the distribution of dust sources inner the plateau, the spatial and temporal variability of dust initiation, and the contribution of dust to the air column above the TP are still controversial. The harsh natural environment of the plateau limits ground-based observations, and satellite observations do not provide adequate information regarding the sand initiation process and the amount of sand initiation in the interior of the plateau owing to low resolution and instrumental observation techniques. The Weather Research and Forecasting model with Chemistry (WRF-Chem) is based on a mesoscale weather model and can partially compensate for the temporal and spatial deficiencies of the observations by simulating the meteorological field while reproducing the long-range transport of dust, providing quantitative information on dust emissions and radiative impact. In this study, the main body of the plateau was divided into three regions, the western, southern, and northern parts, based on surface and climate characteristics. A quantitative study of the spatial and temporal variability of dust fluxes and atmospheric dust properties of different climatic regions in the interior of the plateau was conducted using WRF-Chem in three regions over a three-year period (2004-

2006) with high resolution. Details regarding model construction, data processing and zoning are presented in the next section. Section 3 assesses the accuracy of the simulation results, and in Section 4 we analyze the temporal and spatial variability of sand fluxes, followed by a study of the annual variability and vertical distribution of dust column concentrations over the plateau. A summary of our findings is presented in Section 5."

6. If the authors add the model evaluation of AOD between the results of WRF and MODIS or MISR, cross sections of dust extinction coefficient between the results of WRF and CALIPSO, the results will be more reliable.

[Response] Thank you for your comment. According to annual variation in dust loading in three regions on the Tibetan Plateau (Figure 7), we compared data of average monthly AOD between the results of WRF and MODIS on April as following. They show that the simulation results were consistent with the spatial distribution of the MODIS data， but numerically lower than MODIS.

However, this article focused on the dust in the interior of the Tibetan Plateau while MODIS observe dust from global sources. Therefore, although comparison of the results verifies that the simulation data is reliable, this part of the result is not added to the article. If necessary, we will upload it to supplement.



7. The language of this manuscript needs editing by a native speaker.

[Response] Thank you. The language of this manuscript was edited by a native speaker.

Other comments

1. Line 36, the definition of the Tibetan Plateau

[Response] Thank you**.** The definition of the Tibetan Plateau has been introduction at main comment 1. And "The Tibetan Plateau (TP) is the highest-elevated landmark in the world, with elevations ranging from approximately 1500 to 5000 m above sea level." Can be found in Liu et al., 2019.

2. Line 45, Batangilin Desert? Is it Badanjilin Desert/ Badain Jaran Desert?

[Response] Thank you. This error has been corrected

"There are many well-known dust source areas around the TP, such as the Taklamakan Desert, Thar Desert of India, Badain Jaran Desert, and Gurbantung Desert."

3. Line 53, the unit of 6.6G is "g" or "ton"?

[Response] Thank you. This error has been corrected

"This caused the dust to breake through the planetary boundary layer and extend into the upper troposphere in the northern part of the plateau and produced an average daily transport of 6.6 Gg of dust from the Taklamakan Desert to the TP over the 5 days of the event."

4. Lines 79-82, the inner dust sources on the Tibetan Plateau are clear, please read Wu et al., 2013, Quaternary Science Reviews (http://dx.doi.org/10.1016/j.quascirev.2012.10.003).

[Response] Thank you for the references that you listed, I have studied these article carefully, this article present the detailed dust history from 1850 to 2004 AD on an annual timescale from a shallow ice core from Tanggula, central Tibetan Plateau. The analysis leads to the conclusion that Tarim Basin and over the western Tibetan Plateau, are possible source areas. They also ensure that dust come from Udaoliang made up the largest proportion of the ice core record period. Tanggula Mountains are so far and high-elevated to be the representative of inland of the Tibetan Plateau, and the reestablishment of dust spatiotemporal distribution could be promoted with corporation between numerical simulation and climatological records, such as ice core. However, the dust sources and relative importance are still controversial, there are a lot of dust that cannot be transported to the Tanggula Mountains.

"At present, there are a few studies on dust inner the plateau, and conclusions regarding the distribution of dust sources inner the plateau, the spatial and temporal variability of dust initiation, and the contribution of dust to the air column above the TP are still controversial."

5. Line 93, similar to former major concern, why only choose 2004-2006?

[Response] Thank you. The definition of the Tibetan Plateau has been introduction at main comment 3.

6. Lines 101-102, I strongly suggest the authors provide a map of sand dunes and deserted land on the Tibetan Plateau in the manuscript or in the supporting information

[Response] Thank you. The map of sand dunes and deserted land on the Tibetan Plateau can be found in Fang, 2004; Han et al., 2009.

"The widespread sand dunes and deserted land on the TP provide a large amount of raw material for the generation of dust storms(Fang, 2004; Han et al., 2009)"

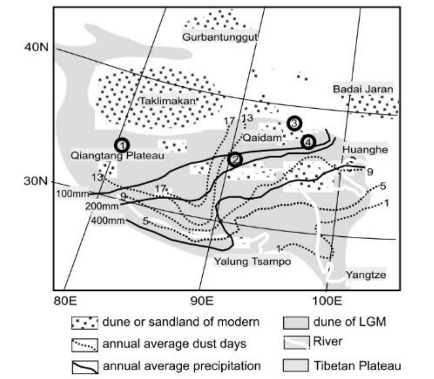


Fig. 1. Distribution of the modern and last glacial sand dunes, desertified sandy land, and the mean annual dust storm days and precipitation from 1961 to 2000 on the TP (black solid line: precipitation; black dashed: dust storm days; black circle including the number representing the following locations: 1, Guliya ice core; 2, Malan ice core; 3, Dunde ice core; 4, Delingha tree ring).

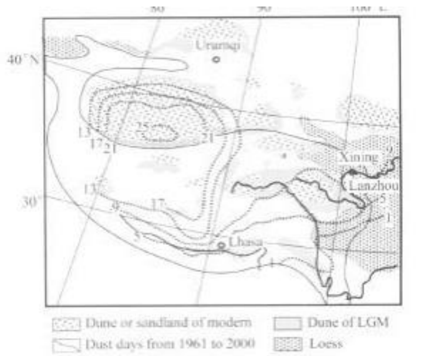


Fig. 1. The distribution map of modern and last glacial sand dunes, desertified sandy land and loess and the spatial mean annual days plot of dust storm from 1961 to 2000 on the Tibetan Plateau. Aeolian sand and loess distribution was drawn according to our field investigation and refs. [1—5], [9—12] and [19—21]. Dust storm data are from the Climate Center of China Meteorological Administration.

7. Lines 102-115, the climate patterns are the basis for the division of the three regions on the Tibetan Plateau. The authors should read some most recent papers about the climate modes on the Tibetan Plateau, redefine the three regions and rewrite this paragraph.

[Response] Thank you. The definition of the Tibetan Plateau has been introduction at main comment 2.

8. Fig 1. The north and south are wrongly labeled, the authors should better add the variation of meteorological parameters such as temperature and precipitation of these three regions.

[Response] Thank you. This error has been corrected, the variation of meteorological parameters such as temperature and precipitation of these three regions can be found in Jiang and Wang, 2001.

9. Line 206, Gondola Mountains?

[Response] Thank you. This error has been corrected

"except for the area where the Gangdise Mountains are located"

10. Lines 236-236, are you sure that the modern East Asian summer monsoon can reach the Qaidam Basin and cause heavy rainfall? If yes, please cite the suitable references. To our knowledge, the maximum of the East Asian summer monsoon is around Lenglongling in the eastern Qilian Mountains.

[Response] Thank you. The suitable reference was cited. Xv et al., 2011 (https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2010JD015053)

"In summer, the Qaidam Basin is primarily affected by the East Asian summer wind, and local heavy rainfall, hail, and other strong convective weather are prone to occur, thus causing local windy weather (Zhang et al., 2014; Xu et al., 2011)."

11. Lines 271, "the dust in the north stayed in the atmosphere for a long period of time", does this mean the potential effects of dust from the Tarim basin?

[Response] Thank you. In fact, some of the dust over the northern region indeed came from the Tarim Basin. But the Figure 5 in this article shows that there are many dust sources in the northern region. Compared with western region, more man-made events are reported here. And compared with southern region, precipitation is less here. These reasons make the dust in the north stayed in the atmosphere for a long period of time

12. Lines 289-291, the western Tibetan Plateau is mainly the Qiangtang Basin, the landscape consists planation surface

[Response] Thank you. Our team has carried out long-term aerosol sampling and observation experiments in the Ali region (Zhang et al., 2021, https://doi.org/10.1029/2020JD033286). At present, our team are still sampling around the Tibetan Plateau. They did observe sand dunes and permafrost.

13. Lines 304-305, the height 8 km above sea level reaches the middle-upper troposphere, does this meant the height of the boundary layer over the Tibetan Plateau was about 3-4 km above the ground level?

[Response] Thank you. The height of 8 km is come from Chen et al. 2013. We chose the highest altitude to be the dividing line in order to ensure dust that once overpasses it can't drop back to the ground.

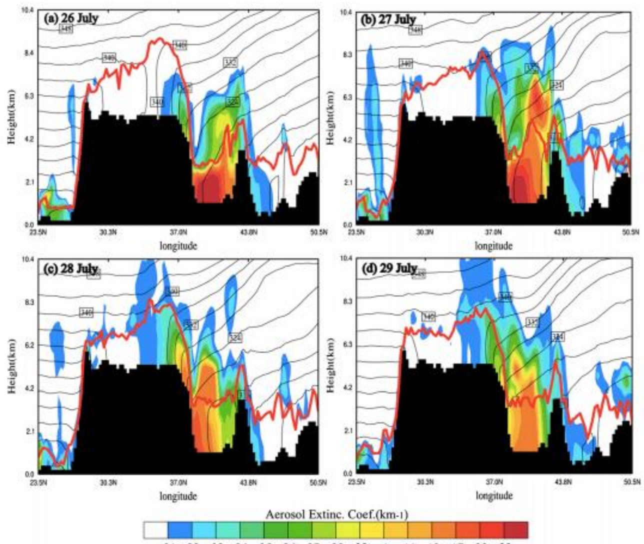


Figure 9. (a–d) Vertical-latitude cross-section at 85.5°E of daily averaged aerosol extinction coefficient and potential temperature on 26–29 July from the WRF-Chem simulations over domain 1. Black contours indicate the potential temperature. The red line represents the daily averaged planetary boundary layer height (PBLH).

14. Please add the linkages of the meteorological and other dataset used in this paper in the Acknowledgement section.

[Response] Thank you. The linkages of the meteorological and other dataset used in this paper in the Acknowledgement section were added.

"We thank to the MERRA-2 reanalysis data were provided by NASA (https://disc.gsfc.nasa.gov/) and the wind speed and temperature observations from 19 stations in the Tibetan region provided by the China Meteorological Data Network (http://data.cma.cn/). We also thank the Land cover products (https://zenodo.org/record/4280923#.Yzg4dmu-vqA). The authors acknowledge support from the Second Tibetan Plateau Scientific Expedition and Research Program (STEP) (No. 2019QZKK0602) and support from Supercomputing Center of Lanzhou University. We also acknowledge the editor Stelios Kazadzis and two referees."

15. References should be updated. For instance, line 489 "Journal of geophysical research. Atmospheres: JGR, 124, 8043-8064" is not correct.

[Response] Thank you. This error has been corrected

"Wu, M., Liu, X., Yang, K., Luo, T., Wang, Z., Wu, C., Zhang, K., Yu, H., and Darmenov, A.: Modeling Dust in East Asia by CESM and Sources of Biases, Journal of geophysical research: Atmospheres, 124, 8043-8064, 10.1029/2019JD030799, 2019."

16. Please check all the reference format. Like in line 55, 61, "the results of Wang(Wang et al., 2021)" , "Hu(Hu et al., 2020)", not correct.

[Response] Thank you. This error has been corrected