Response to Referee #2: We would like to thank the referee for the careful review and suggestion, which helps us to further improve the quality of the manuscript.

Our response follows (*the reviewer's comments are in italics and blue*)

General comments: The authors present the emission inversion of 2021 super sandstorms in East Asia. The dust emissions are optimized based on a four-dimensional variational (4DVar) data assimilation and observations including both satellite AOD and groud-based PM10 data. With the newly inversed dust emission field, source apportionment experiments are also carried out. The study quantifies the relative contribution of Mongolian and Chinese source to the dust deposition in the two north China mega-city regions (Fenwei and North China Plain). Generally speaking, the paper is well written and scientific sound. There are however some aspects that should be explained before it can be published. I have some questions for the authors and some comments that could help to improve the manuscript.

1)Page 11, line 5. They should acknowledge emission uncertainty might not be the dominant source in the three dust events. Afterall, they state in Section 4.1.2, page 15, line 14 "This suggests that the dust plume in the higher layers moves faster, and is in further southeast than the dust cloud at bottom layer. However, this feature is not correctly captured by our LOTOS-EUROS/dust model." They indicate here error might also rise from the advection transport next to the emission uncertainty. Then it is also recommended to discuss the difficult or possibility of handling the emission and transport error at the same time.

Reply: Uncertainty in the transport is of course part of the dust simulation error source and should be emphasized. Remarks are now added in page 11, line 23-25 by saying "***In this study, we define the main model uncertainty to be in the parametrization of the dust emissions. Although other model processes such as transport and deposition are uncertain too, for the events studied here these assumed to be of less importance than the location and the intensity of dust emission.***"

Discussions are also added about how to handle the correct the error from the advection transport in page 17, line 13-17: "***The mismatch in simulated vertical structure is mostly likely caused by uncertainty in the advection transport. The two-dimensional grid distortion technique (Jin et al., 2021) which is independent on the emission inversion could adjust the horizontal position of the dust cloud simulation to better fit the available measurements, but***

is not yet able to adjust the vertical structure as is required here. A three-dimensional grid distortion with data that measuring the vertical profile of dust cloud is planned to solve this issue in our future research."

2)Page 16 Sect 4.2, the authors are omitting a discussion why source apportion is focusing on the Mongolia and China desert source. Is it because the different desertification situation in Mongolia or China, or their results could help the greenness recover in China and Mongolia in the future? This is important for reader while introducing the source apportionment experiments.

Reply: Definitely, it should be explained that why we focus on the contribution of Mongolian dust and Chinese dust. Remarks are added in page 18, line 30-33 and page 19, line 1-5, by saying ***"China government has launched several large-scale ecological engineering projects to combat the environmental problems in the northern China during recent decades. One of the largest is the Three-North Shelter Forest Program, which aimed at increasing the vegetation cover upto 15% by 2050 (Niu et al., 2019). Several studies (Shao et al., 2013; Tan and Li, 2015) reported that the vegetation recover weakened dust storms substantially. In contrast, Mongolia has experienced the ever-increasing land degradation and desertification (Meng et al., 2020), which aggravates the spring dust storms (Han et al., 2021). To evaluate the roles of Mongolian and Chinese Gobi deserts in the 2021 super sandstorms quantitatively, source apportionment tests based on the estimated emission field are carried out further. These source apportionment tests focus on the two dust-affected mega-city clusters in the northern China, North China Plain (NCP) and Fenwei Plain (FWP), and aims to calculated whether the dust originates from transnational transport from Mongolia or from domestic sources in China."***

Specific comments:

Page 1, Line 18: 'partical' → 'particle'

Reply: corrected.

Page 2, Line 23: 'consists' → 'consist'

Reply: corrected.

Page 2, Line 34: 'differencec' → 'differences'

Reply: corrected.

Page 3, Line 26: 'where' → 'were' ?

Reply: corrected.

Page 4, Line 29: 'Similar for PM10 a non-dust bias correction as used in Jin et al. (2019a, 2021) is adopted in this work' → 'Similar for PM10, a non-dust bias correction as used in Jin tt al. (2019a, 2021), is adopted in this work' .

Reply: accepted.

Page 11, Line 11: 'Fh' → 'fh'?

Reply: accepted.

Page 13, Line 11: remove 'the'

Reply: "***a new the emission is estimated***" is now changed to "***the emission field is estimated***"

Page 13, Line 31: 'emisison' → 'emission'.

Reply: corrected.

Page 15, Line 13: 'visilbe' → 'visible'.

Reply: corrected.

Page 15, Line 24: should be 'The standard model simulated AOD values are even larger than 4'.

Reply: accepted.

Page 15, Line 32: 'concentations' → 'concentrations'.

Reply: accepted.

Page 16, Line 7: 'accurate' → 'accurately'.

Reply: accepted.

Page 16, Line 22: 'effect' → 'affecting'?

Reply: corrected.

Figure 6 the title of the panels using SDS should be consistent with the text using SD.

Reply: The Figure 6 is updated as follow.

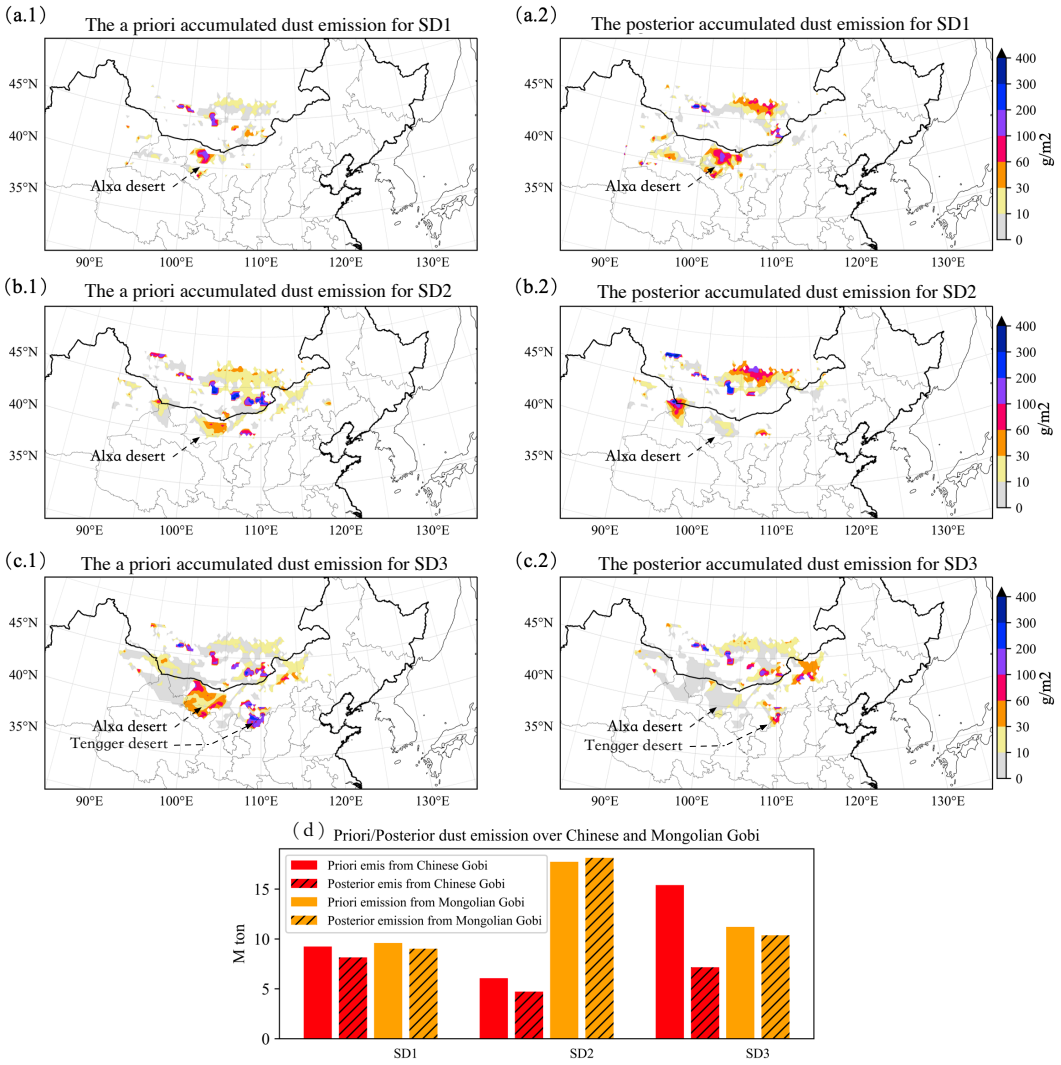

Figure 6. Distribution of the a priori (a.1-c.1) and posterior (a.2-c.2) accumulated dust emission for the SD1, SD2 and SD3; the total priori and posterior emission either from China or from Mongolia during SD1, SD2 and SD3 (d).