

Response to the Reviewers:

We sincerely thank the reviewers for their insightful comments and constructive suggestions. We have carefully addressed each point raised and made substantial revisions accordingly. Below, we provide detailed responses to all comments, with the reviewers' original remarks shown in black and our responses presented in blue. To facilitate the review process, we have included the relevant revised text sections to illustrate how each suggestion has been incorporated into the updated manuscript.

Comments

1. The authors frequently mention that metal ions can catalyze the generation of ROS, leading to higher OP values. However, since metal ions were not measured in this study, such assumptions should be better supported. For instance, the statement “Due to differences in geological background, dust from different regions exhibits significant variations in mineral composition, leading to differences in their oxidative activity.” Requires stronger documentation. Is there any evidence in the literature supporting these differences in mineral composition?

Response: We sincerely appreciate the reviewer's important comment. We fully agree with your observation that the discussion regarding metal ion-catalyzed ROS generation and the variation in mineral composition due to geological background differences indeed requires stronger literature support. In response to your suggestion, we have added important supporting references in the revised manuscript to strengthen this discussion. We have newly cited the research by Gonçalves Ageitos, M. et al. (2023), Jeong (2024) and Nishita-Hara et al. (2023), which provide support for our discussion on how geological background differences lead to variations in mineral composition and their contribution to OP. Lines 614-616 have been modified to: “Due to differences in geological background, dust from different regions exhibits significant variations in mineral composition, leading to differences in their oxidative

activity (Gonçalves Ageitos et al., 2023; Jeong, 2024; Nishita-Hara et al., 2023).”

2. After revision of the PMF analyses, the results now show only two biomass burning factors (NN and ZZ sites). Could the authors provide an explanation for why this factor was not identified at the other sites, e.g. at the rural site, where biomass burning is typically expected?

Response: **Thank you for your careful review.** Regarding the phenomenon that biomass burning factors were identified only at the NN and ZZ sites, **we provide the following specific explanations based on the geographical characteristics of each site:**

(1) Sites where biomass burning factors were identified:

The **NN site** is located in the subtropical region of southern China, which is an important sugarcane cultivation area. During the sugarcane harvest season from November to March each year, extensive burning of sugarcane leaves results in significant biomass burning signatures. The **ZZ site** is situated in the agricultural core area of the Central Plains of China, a major production region for wheat and corn. Large-scale straw burning activities occur frequently during the wheat harvest in June and the corn harvest in October.

(2) Sites where independent biomass burning factors were not identified:

Although the **GC site** is a rural station, this region has implemented strict straw burning prohibition policies since 2016, significantly reducing biomass burning activities. The “chloride-rich combustion” factor we identified may include some other burning activities, but its characteristics are masked by other chloride-containing sources (such as waste incineration and plastic burning). The **LFS site** is located in a remote area of Northeast China with low annual average temperatures and a short growing season (May-September). This region has long winters (October to April), the ground is snow-covered for most of the sampling period, limiting open burning activities. The identified “chloride-rich combustion” factor may contain biomass burning related to winter heating mixed with coal combustion, which prevented the formation of an independent biomass burning factor.