Reply to Referee 1:

The study evaluated the intensity of dust weather from PM_{10} concentrations and identified the synoptic systems and related dynamic mechanisms that caused different intensities of dust weather in North China. In addition to the well-known Mongolian cyclone that had received much attention in recent years, the Mongolian cold high was also responsible for dust weather in North China. Considering both the Mongolian cyclone and the cold high for forecasting, a common predictor was proposed. The results of this study could provide references for the forecasting of dust weather and climate prediction. **This paper is well written and organized. I recommend it to be published in ACP after several minor corrections.**

Major comments:

1. In Section 2.2, the identification method of the Mongolian cyclone was described based on its definition, but the description was not very specific. Could further details be provided?

Reply:

The method used in this article to identify the Mongolian cyclone is based on the meteorological definition of the extratropical cyclone (Shou, 2006). The **specific identification steps** are as follows: First, locate the lowest sea level pressure (SLP) within the range of **40–55°N, 100–130°E**. If the **lowest SLP is less than or equal to 1010 hPa**, then proceed to calculate the average value of the **pressure gradient within a range of ±2.5° latitude and longitude around the lowest SLP**. If the average pressure gradient is greater than or equal to 0.55 hPa per 100 km, the presence of the Mongolian cyclone is confirmed; otherwise, the Mongolian cyclone is considered not to exist. The more precise description of the method for identifying Mongolian cyclones has been revised.

Related References:

Shou S. W.: Synoptic Analysis, China Meteorological Press, Beijing, 361 pp., ISBN 9787502934576, 2006 (in Chinese).

Revision:

p. 3, line 90–93: According to the synoptic definition of the extratropical cyclone (Shou, 2006), the Mongolian cyclone was identified based on the following criteria: (1)

The **lowest SLP** within the range of **40–55°N, 100–130°E** should not exceed **1010 hPa.**

(2) The **average pressure gradient** within a **±2.5° latitude and longitude range** around the lowest SLP must be equal to or greater than **0.55 hPa per 100 km**. The vertical air temperature …

2. Section 5 focused on the common predictor of the MC type and the CH type. However, the improvement and advantage of this common predictor, compared to solely considering the Mongolian cyclone, are not clearly articulated in the text. It is recommended to provide further elaboration on this point to enhance clarity and understanding.

Reply:

Previous studies have generally highlighted the significant role of Mongolian cyclones in dust weather in North China (Wu et al., 2016; Bueh et al., 2022; Gao et al., 2024). This study emphasized the role of other systems, mainly cold high, in addition to Mongolian cyclones. By solely focusing on Mongolian cyclones, the influence of **other systems** on North China's dust weather (accounted for **38.3%**) would be **overlooked**. Based on ERA5 reanalysis data from 2015 to 2023, the dust capture rate of the common predictor is **76.5%**, which **captures more dust days** compared to solely considering the Mongolian cyclone (**61.7%**). Furthermore, the ability of the **C3S seasonal forecast model to reproduce I_ACA-CA** was further assessed. The I_ACA-CA calculated by ECMWF, DWD, and MF seasonal forecast models with a one-month lead captured around 50% of spring dust days when positive. It is worth noting that due to the lower spatial resolution (1°×1°) of the C3S model forecast data relative to the ERA5 data (0.25°×0.25°), the **SLP produced by the C3S model failed to effectively identify the presence of the Mongolian cyclone**. Therefore, the introduction of the common predictor (I_ACA-CA) is of great significance for dust weather prediction in NC. In the discussion section, explanations of the advantages of the common predictor over solely considering Mongolian cyclones were added.

Related References:

Bueh, C., Zhuge, A., Xie, Z., Yong, M., and Purevjav, G.: The development of a powerful Mongolian cyclone on 14–15 March 2021: Eddy energy analysis, AOSL., 15, 100259, https://doi.org/10.1016/j.aosl.2022.100259, 2022.

Gao, J., Ding, T., and Gao, H.: Dominant circulation pattern and moving path of the Mongolian Cyclone for the severe sand and dust storm in China, Atmos. Res., 301, 107272, https://doi.org/10.1016/j.atmosres.2024.107272, 2024.

Wu, C. L., Lin, Z. H., He, J. X., Zhang, M. H., Liu, X. H., Zhang, R. J., and Brown, H.: A process-oriented evaluation of dust emission parameterizations in CESM: Simulation of a typical severe dust storm in East Asia, J. Adv. Model. Earth Syst., 8, 1432–1452, C10.1002/2016MS000723, 2016.

Revision:

p. 13, line 292: …The common predictor offers a more **comprehensive prediction** for both types of dust weather compared to solely considering the Mongolian cyclone, capturing more dust days. The ability of the C3S seasonal forecast model…

3. In Section 6, the ability of the C3S model to reproduce I_ACA-CA was discussed, but only the ECMWF SEAS5.1 was considered. Why was only the predictive ability of one model considered? Is there a certain degree of randomness involved? It is recommended to also compare and evaluate the capabilities of other systems.

Reply:

Thank you for your suggestions. Among C3S models, only **ECMWF SEAS5.1 has continuous data for Z500 from 2015 to 2023**. **Deutscher Wetterdienst (DWD) and Météo-France** have data for 2015-2023 **but from different system versions**, while **other institution systems have missing data for certain years**. Therefore, we conducted additional analysis of the capabilities of the **DWD forecast systems (GCFS2.0 & GCFS2.1)** and **Météo-France forecast systems (System6 & System7 & System8)** to reproduce I_ACA-CA, and compared them with ECMWF SEAS5.1.

Although there may be some deviations when using data from different versions of systems simultaneously, we still utilized forecast data from the DWD and MF systems to calculate I_ACA-CA for comparison. The I_ACA-CA calculated by **ECMWF**, **DWD, and MF seasonal forecast models** with a one-month lead captured **46.1%**, **52.2%, and 51.3%** of spring dust days when positive. The capture rates are all **around 50%**, indicating that using only one model has **no randomness**. The **discussion** on the **ability of DWD and MF** seasonal forecast models to reproduce

I_ACA-CA has been added.

Revision:

p. 3, line 84-86: … Environmental Information (Vermote, 2019). The Copernicus Climate Change Service (C3S, 2018) provided seasonal forecast products from European Centre for Medium-Range Weather Forecasts (ECMWF) SEAS5.1, **Deutscher Wetterdienst (DWD) GCFS2.0 & GCFS2.1**, and **Météo-France (MF) System6 & System7 & System8**. In this study …

p. 13, line 292-295: … The ability of the C3S seasonal forecast model to reproduce I_ACA-CA was further assessed. The I_ACA-CA calculated by ECMWF, **DWD, and MF seasonal forecast models** with a one-month lead captured **around 50%** of spring dust days when positive.

Specific comments:

1. Lines 114-115: The sentence: “the main surface synoptic systems for the two types of Dust days were the Mongolian cyclone and cold high” is ambiguous. "According to the context of the text, it is proposed to be modified as: “the main surface synoptic systems for the two types of Dust days were the Mongolian cyclone and cold high respectively”.

Reply:

Thank you for your advice. This sentence has been **revised** according to the suggestion.

Revision:

p. 4, line 114-115: … the main surface synoptic systems for the two types of Dust days were the Mongolian cyclone and cold high respectively …

2. The abstract states that the Mongolian cyclone type accounts for 62.4%, with the remaining 37.6% being the cold high type. However, based on Fig. 1, it seems like both of the types together make up 62.4%. The percentages labeling in Fig. 1 are misleading. It is recommended to make corrections.

Reply:

Thank you for your advice. In order to avoid confusion, the percentages in Fig. 1 have been **removed**.

Revision:

p. 5, line 134-140:

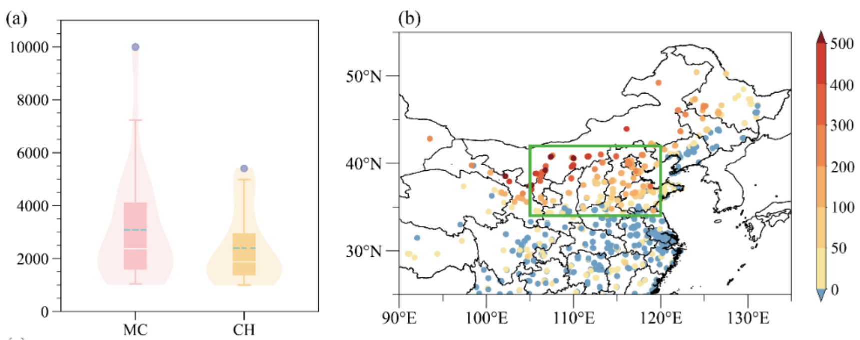

Figure 1. (a) Boxplots of daily maximum PM_{10} concentrations (units: μg m^{-3}) in NC during MC days (pink) and CH days (orange). The cyan dashed lines and blue dots in the boxplot represent average PM_{10} concentrations and outlier values. Density distributions of PM_{10} concentrations are shown by pink and orange shadings for MC days and CH days respectively. (b) The composite differences of observed daily maximum PM_{10} concentrations (scatter, units: μg m^{-3}) during MC days relative to CH days. The green box indicates NC.

3. Based on the content in the main text, the meteorological indices in Table 1 are calculated corresponding to the area with the most significant correlation coefficients with the daily maximum PM_{10} concentrations. It is recommended that, the corresponding regions where the indices are calculated should be clearly marked on the map to make the definition of the indices more explicit and clearer.

Reply:

To provide a more intuitive display of the corresponding regions for calculating the meteorological indices, these areas have been marked with black boxes.

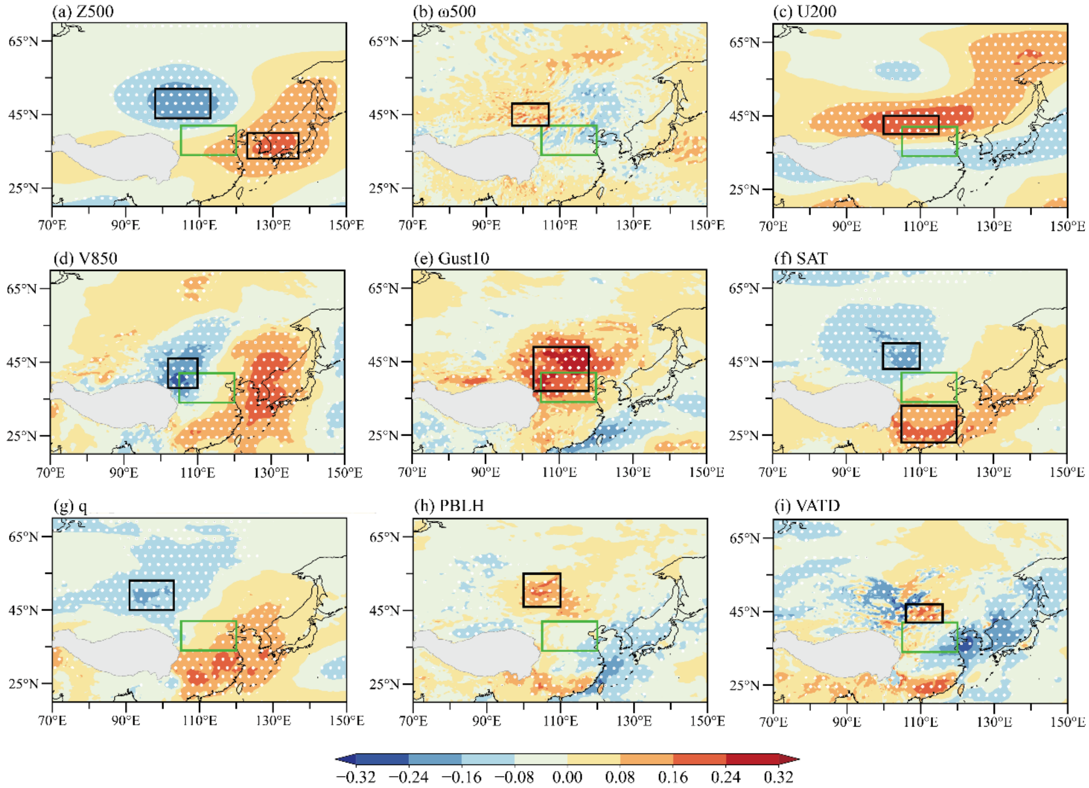

Figure R1. Correlation coefficients of observed daily maximum PM_{10} concentrations over NC with daily (a) Z500, (b) ω500, (c) U200, (d) V850, (e) Gust10, (f) SAT, (g) q, (h) PBLH, and (i) VATD in spring from 2015 to 2023. White dots indicate that correlation coefficients exceed the 95% confidence level. The green boxes in panel (a)–(i) represent NC. The black boxes in panel (a)–(i) represent the regions for calculating the indices in Table 1 respectively.

4. The "L" and "H" in Fig. 7 are not explained in the caption, please add clarification.

Reply:

The descriptions of the meanings of "L" and "H" have been added to the caption of the figure.

Revision:

p. 14, line 310-317:

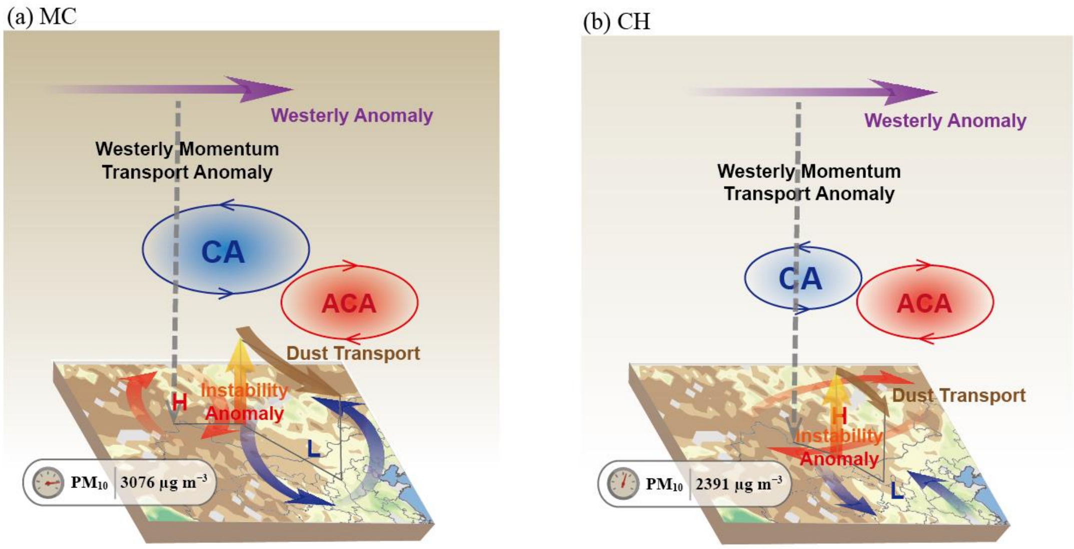

Figure 8. Schematic diagram for the three-dimensional atmospheric circulation anomalies and related dynamic processes of (a) MC type and (b) CH type dust weather with distinct PM_{10} concentrations in NC. 500 hPa cyclonic anomaly (CA) and anticyclonic anomaly (ACA) are the key anomalous circulation systems for the two types. **"L" and "H"** respectively represent **surface low-pressure anomalies** and **high-pressure anomalies**. The anomalous gust winds and thermal instability near the dust source area favored dust lifting. Enhanced 200 hPa westerly winds, with momentum transport downward, favored further increases in surface wind speeds. Anomalous northerly winds facilitated the emission and transport of dust particles. The shading on the surface represents NDVI in March 2023. The directions of the arrows indicate anomalous airflow directions. The average PM_{10} concentrations of MC and CH days are demonstrated in the left bottom of each panel.

5. Line 318: The period after the subheading should be removed.

Reply:

The period after the subheading has been removed.

Revision:

p. 15, line 318: Data Availability

6. Line 36 in Supplement: There is an error in the caption of Fig. S5: "zonal wind" should be "meridional wind".

Reply:

This error has been revised. Composite anomalies of meridional component of the vertical circulation during CH days in the supplement have been moved to Fig. 4 in the revised manuscript.

Revision:

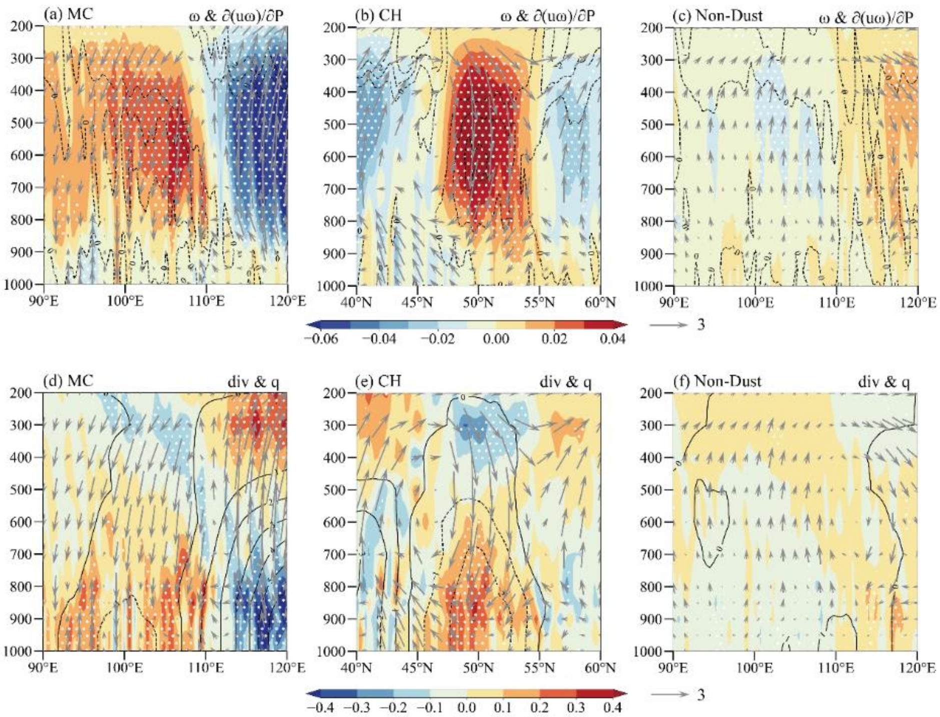

Figure 4. Composite anomalies of zonal component of the vertical circulation average over 40–60°N, 90–120°E during MC days: (a) The variables include ω (shading, units: Pa s^{-1}) and downward transport of westerly momentum (<0, dashed contour, units: 10^{-3} m s^{-2}). White dots indicate that ω anomalies exceed the 95% confidence level. The vectors represent ω (magnified 100 times) and zonal wind. (d) The variables include divergence (shading, units: 10^{-5} s^{-1}) and q (contour, units: 10^{-4} kg kg^{-1}). White dots indicate that divergence anomalies exceed the 95% confidence level. The vectors represent ω (magnified 100 times) and zonal wind. Panel (c) and (f) are the same as panel (a) and (d) respectively, but for Non-Dust days. Composite anomalies of meridional component of the vertical circulation average over 40–60° N, 90–120° E during CH days: (b) The variables include ω (shading, units: Pa s^{-1}) and downward transport of westerly momentum (<0, dashed contour, units: 10^{-3} m s^{-2}). White dots indicate that ω anomalies exceed the 95% confidence level. The vectors represent ω (magnified 100 times) and **meridional** wind. (e) The variables include divergence (shading, units: 10^{-5} s^{-1}) and q (contour, units: 10^{-4} kg kg^{-1}). White dots indicate that divergence anomalies exceed the 95% confidence level. The vectors represent ω (magnified 100 times) and **meridional** wind.