Dear Editors and Reviewers,

Thank you very much for your careful review and helpful comments on our manuscript egusphere-2024-2493. We appreciate very much your constructive comments and encouraging suggestions on our manuscript. We have accordingly made the careful revisions. The revised portions are highlighted in the revised manuscript. Please find our point to point responses to the reviewer's comments as follows:

Responses to the reviewer 1

[This paper investigates the quasi-weekly oscillation of $PM_{2.5}$ transport over China. The period analysed extended during the winters of 2015-2019 and $PM_{2.5}$ concentrations included data from 1079 stations. The statistical procedure considered the extended empirical orthogonal function. Two transport flux patterns were identified and 8 phases of the regional $PM_{2.5}$ transport over central and eastern China were isolated. Moreover, the synoptic pattern influence on the quasi-weekly oscillation of the regional $PM_{2.5}$ transport was analysed. Since this is a complex study, the paper may be accepted for publication in Atmospheric Chemistry and Physics after the inclusion of the following minor changes.]

Response 1: We appreciate very much your constructive comments and encouraging suggestions on our manuscript. We have accordingly made the careful revisions. The revised portions are highlighted in the revised manuscript. Please find our point to point responses to the reviewer's comments as follows:

[The authors have identified this quasi-weekly oscillation with a complex statistical procedure. Potential readers could ask if this oscillation could be observed with simpler procedures. If this oscillation responds to an atmospheric pattern, perhaps it could be perceived by direct measurements. If this oscillation responds to an atmospheric pattern, the authors should highlight the main advantages of the employed procedure (extended empirical orthogonal function), which is not easy,

against other procedures. Moreover, the authors should indicate if alternative and simple procedures exist to get similar results.]

Response 2: Many thanks for the encouraging comments and helpful suggestions on our manuscript. Following the reviewer's comments, we have accordingly revised the manuscript in lines 232-234, lines 248-252 and lines 468-480.

The EEOF analysis with the temporal lag of the spatial fields is able to better characterize the spatial and temporal evolution of perturbations, especially propagating waves in the atmosphere (Weare and Nasstrom, 1982; Qian et al., 2019; Yang et al., 2024b). Due to its technical advantages, the EEOF method is commonly employed to extract atmospheric oscillation patterns to reveal the impacts and mechanisms of atmospheric fluctuations and monsoon circulation on regional weather, climate, and atmospheric environments (Dey et al., 2018; Qian et al., 2019; Yang et al., 2024b). In this study, we employed the EEOF method to identify regional $PM_{2.5}$ transport modes in synoptic scale, by constructing $PM_{2.5}$ transport flux vectors (TFV) and the magnitude (TFM) with the product of near-surface $PM_{2.5}$ concentrations and wind components at 1079 stations across China during the winters of 2015-2019. We performed EEOF analysis on $PM_{2.5}$ TFV and TFM, resulting in the spatial structure of $PM_{2.5}$ transport flux under the temporal disturbances at the synoptic scale, and revealing the connection between synoptic-scale disturbances in the EAWM and QWO in regional $PM_{2.5}$ transport in CEC. **(in Section 4, lines 468-480)**

EEOF is an extension of the EOF to analyze the autocorrelations of the variable field over time. By selecting a lag time, the original observational matrix is expanded into multiple continuous time matrices, diagnosing the temporal changes in the spatial structure of variable fields. **(in Section 2.4, lines 232-234)**

Additionally, existing studies have utilized wavelet analysis, power spectrum analysis, and band-pass filtering methods to extract intraseasonal oscillation sequences of regional $PM_{2.5}$ concentrations (An et al., 2022; Gao et al., 2020; Li et al., 2021; Liu et al., 2022; Wu et al., 2023; Yang et al., 2024b). Such approaches may serve as alternative methods to EEOF analysis for establishing the quasi-weekly lifecycle of regional $PM_{2.5}$ transport. **(in Section 2.4, lines 248-252)**

Additionally, we have refined the explanation of the filtering of atmospheric periodic variations in Section 2.3, which discusses the Butterworth filter method **(lines 177-189)**.

Atmospheric motion encompasses a variety of temporal and spatial scales. The sequences of meteorological variables often contain complex periodic components and exhibit multi-time-scale variations, including daily, weekly, seasonal, and interannual variations. Numerous observations have found QWO with periods of less than 10 days across various meteorological elements in the EAWM system (Compo et al., 1999; Murakami, 1979; Wu and Wang, 2002). Synoptic-scale atmospheric variations are closely related to atmospheric longwave adjustments, with QWO periods of 4-7 days observed in cold air activities of the EAWM (Bai et al., 2022; Wu and Wang, 2002). The synoptic-scale disturbance regulates the generation, transport, and removal of $PM_{2.5}$ in air pollution, which is a key mechanism behind the 4-7 day periodic changes in $PM_{2.5}$ in CEC during the periods of EAWM (Guo et al., 2014; Liu et al., 2018; Quan et al., 2014, 2020). Based on the research objectives, identifying the desired periodic components from the original observational sequences is referred to as sequence filtering. In this study, we employed a Butterworth filter to extract QWO from observational data. **(in Section 2.3, lines 177-189)**

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[The authors should inform about processes similar to that described in this paper around the world. The number of references for discussion should be increased. They should be used to compare results of this study with those from previous analyses. Strengths and weaknesses of the current study should be included.]

Response 3: Following the reviewer's comments, we have accordingly added the information about processes similar to that described in this paper (in Section 4, lines 468-480, lines 492-497), the number of references for discussions and the comparisons of results of this study with those from previous analyses (in Section 3.2, lines 381-391; in Section 4, lines 468-480), as well as the strengths and weaknesses of the current study (in Section 1, lines 92-101; in Section 4, lines 480-486) in the revised manuscript as follows:

Driven by prevailing winds of EAWM, the THB became the main receptor for regional transport of air pollutants over CEC (Bai et al., 2022; Shen et al., 2021). During 2015–2019, approximately 65.2% of the total $PM_{2.5}$ heavy pollution events in the THB were triggered by regional transport of air pollutants over CEC (Hu et al., 2022; Shen et al., 2021). Such $PM_{2.5}$ transport from upstream source regions in CEC contributes 51%-85.7% of the $PM_{2.5}$ pollution over the THB receptor region (Hu et al., 2021; Lu et al., 2017; Shen et al., 2022; Yu et al., 2020), revealing the dominance of regional transport of air pollutants from CEC to the THB with the meteorological drivers. Our research emphasizes the QWO of regional $PM_{2.5}$ transport over CEC with the driver of the synoptic-scale disturbances of EAWM circulation, confirming the source-receptor relationships with their 2-day lagging effects in the regional $PM_{2.5}$

transport between the upstream NCP source region and the THB receptor region. **(in Section 3.2, lines 381-391)**

Previous studies have primarily focused on the relationship between atmospheric intraseasonal oscillations in the mid-to-high latitudes of the Eurasian region and the persistent $PM_{2.5}$ pollution (An et al., 2022; Gao et al., 2020; Li et al., 2021; Liu et al., 2022; Wu et al., 2023; Yang et al., 2024b). $PM_{2.5}$ concentration anomalies in North China exhibit significant lifetimes of 10–30 days, with anticyclonic anomalies and related meteorological conditions (e.g., surface air temperature, boundary layer height) in Northeast Asia influencing local $PM_{2.5}$ accumulation and hygroscopic growth (An et al., 2022; Yang et al., 2024b). These studies have investigated the quasi-biweekly lifecycle of persistent $PM_{2.5}$ pollution events in North China through phase synthesis methods (Gao et al., 2020; Wu et al., 2023; Yang et al., 2024b). However, there remains a lack of systematic studies on the synoptic-scale oscillation of regional $PM_{2.5}$ transport. **(in Section 1, lines 92-101)**

Our study focuses on the driving effects of synoptic-scale disturbances associated with cold air activity with the anomalous northerly winds in EAWM on QWO of regional $PM_{2.5}$ transport over CEC, exacerbating $PM_{2.5}$ pollution in the downwind THB. Differently from the studies on stagnant meteorological conditions associated with $PM_{2.5}$ accumulations (Gao et al., 2020; Wu et al., 2023; Yang et al., 2024b), this study provides new insights into the understanding of regional $PM_{2.5}$ transport with source-receptor relationship with the meteorological mechanism in atmospheric environment change. **(in Section 4, lines 480-486)**

Besides the EEOF method used in this study, the alternative methods of wavelet analysis, power spectrum analysis, and band-pass filtering could be used in further study. Future studies utilizing long-term observations of air pollutants and meteorology over CEC could more comprehensively understand the variations in the regional transport of particles and the gaseous precursors with their contributions to air pollution, through the integration of artificial intelligence and physical-chemical process analyses. **(in Section 4, lines 492-497)**

Also, please find the relative information and discussions in the above response 2 (in Section 4, lines 468-480).

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[Minor remarks: L. 279. "H. Huang" should be "Huang".]

Response 4: Thanks the referee for pointing out the printing errors, which have been corrected in the revised manuscript.