

## Reply to Anonymous Referee #1

This study starts with a comprehensive delineation of an elevated foehn-induced O<sub>3</sub> air pollution event in Beijing. Such a delineation includes the spatial-temporal distribution of surface O<sub>3</sub> in Beijing, the synoptic background, the evolution of vertical air structure, the backward trajectory analysis, cross-section progression, and climatological status. The manuscript is clearly structured and well-written, with figures that are clear and easy to interpret. I would recommend its publication at ACP with the following issues addressed.

**Reply:** Thank you so much for your positive feedback. We have carefully considered your suggestions and comments and have made corresponding revisions and clarifications accordingly.

- 1、 The authors pointed out the distinct impacts of shallow and elevated foehn on O<sub>3</sub> air pollution. Could the authors please add somewhere an illustration of the different progression and structure between shallow and elevated foehn?

**Reply:** Thank you for this constructive comment. In the revised manuscript, we have expanded the discussion on the distinct impacts of shallow and elevated foehn on air pollution. We have included statistics on MDA8O<sub>3</sub> and PM<sub>2.5</sub> pollution during summertime elevated foehn events identified in this study, along with a comparison with shallow foehn events reported in Li et al. (2025) (Table S1). For comparison, we also plotted composite afternoon boundary layer temperature profiles, boundary/residual layer heights, and afternoon boundary layer wind speed profiles before, during, and after 90 shallow foehn events in Beijing, as identified by Li et al. (2025) (Fig. S5).

**Table S1.** Statistics of MDA8O<sub>3</sub> and PM<sub>2.5</sub> pollution for summertime elevated foehn events identify in this study, and their comparison with shallow foehn events identified in Li et al (2025).

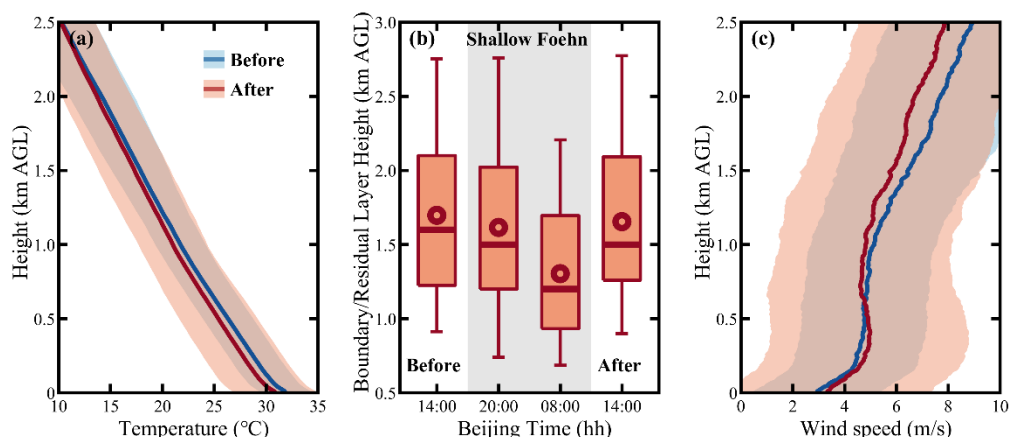
	Average concentration on post-foehn days (μg m <sup>-3</sup> )	Average increasing rate relative to pre-foehn days (%)	Pollution-worsened rate in all cases (%)
Statistics for summertime elevated foehn events (54 cases)			
MDA8O <sub>3</sub>	168.3	32.4	86.7 (46 in 53 cases)
PM <sub>2.5</sub>	32.2	31.5	69.8 (37 in 53 cases)
Statistics for summertime shallow foehn events (90 cases)			
MDA8O <sub>3</sub>	142.9	7.6	55.2 (48 in 87 cases)
PM <sub>2.5</sub>	27.7	-2.5	55.2 (48 in 87 cases)

Note: Pollution data were missing for one day in the elevated foehn events and for three days in the shallow foehn events. The summertime shallow foehn events were identified over the period 2015–2020, which differs from the elevated foehn events identified over 2015–2024.

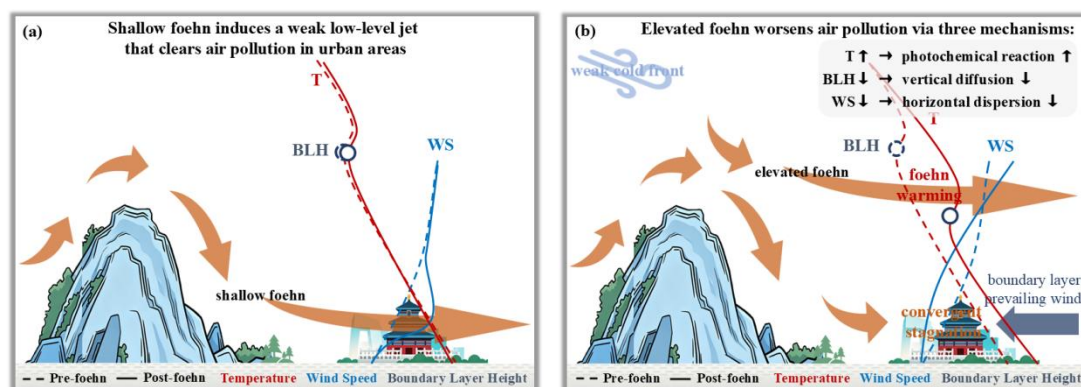
The comparison indicates that elevated foehn exacerbates not only O<sub>3</sub> pollution but also PM<sub>2.5</sub> pollution, making it a more reliable meteorological precursor for air pollution warnings than shallow foehn. While shallow foehn induces a weak low-level jet that cleanses air pollution, elevated foehn worsens air quality through three primary

mechanisms: (1) increasing boundary layer temperature, thereby enhancing photochemical formation; (2) reducing residual/boundary layer height, thereby inhibiting vertical diffusion of pollutants; and (3) slowing boundary layer winds, thereby suppressing horizontal dispersion. [Lines: 447-458.](#)

In light of the above mechanisms, we added a conceptual diagram in the revised manuscript (Fig. 13) to illustrate the differing pollution mechanisms associated with shallow versus elevated foehn.



**Figure S5.** Composite of (a) afternoon boundary layer temperature profiles, (b) boundary/residual layer height, and (c) afternoon boundary layer wind speed profiles before, during, and after 90 shallow foehn events in Beijing, as identified by Li et al (2025). In (a) and (c), solid lines represent the mean profiles and shaded areas indicate the standard deviation. In (b), box-and-whisker plots display the 5th, 25th, 50th, 75th, and 95th percentiles; dots denote the means.



**Figure 13.** Conceptual diagram illustrating the differing pollution mechanisms associated with shallow versus elevated foehn.

2、 One factor for post-foehn O<sub>3</sub> pollution is increased temperature. The author also mentioned in some places in the manuscript that foehn could decrease PM<sub>2.5</sub>. Therefore, I presume that foehn has different or even opposite impacts on O<sub>3</sub> and PM<sub>2.5</sub>, since the former is more sensitive to temperature while the latter is more

affected by diffusion and transport processes. Could the authors please add some clarifications about the possible different impacts of foehn on PM<sub>2.5</sub> and O<sub>3</sub>?

**Reply:** Thank you for this comment. In our original manuscript, we actually compared the worsening effect of elevated foehn on O<sub>3</sub> pollution with the cleaning effect of shallow foehn on PM<sub>2.5</sub> pollution. However, when the respective effects of elevated foehn on O<sub>3</sub> and PM<sub>2.5</sub> are considered on the same scale, both actually show a pollution-worsening effect. In contrast to O<sub>3</sub>, PM<sub>2.5</sub> may be less sensitive to temperature increases, which explains its slightly lower pollution-worsened rate in elevated foehn cases (69.8%). When compared with shallow foehn, elevated foehn exhibits a very weak pollution-worsening effect for both O<sub>3</sub> and PM<sub>2.5</sub>. In other words, it is the foehn type that plays a decisive role, rather than the type of pollutant. In the revised manuscript, we clarified these mechanisms with the addition of Table S1 and Fig. S5. **Lines: 447-458.**

3、So the foehn is a more localized meteorological impact on O<sub>3</sub>, as compared to synoptic-scale meteorology. The authors mentioned in the end to explore the contribution of elevated foehn to O<sub>3</sub> generation under different synoptic backgrounds. Could the authors here illustrate more of this point for the events introduced in this paper? This could be important since there are numerous publications showing the importance of synoptic-scale weather on regional O<sub>3</sub> pollution in the NCP region.

**Reply:** Thank you for this excellent comment. We expanded this point as follows.

“To date, numerous circulation classification-based studies have highlighted the importance of synoptic-scale weather on regional O<sub>3</sub> pollution in the NCP region (Dong et al., 2020; Han et al., 2020; Liao et al., 2024; Liu et al., 2019). However, day-to-day circulation classifications actually overlook sub-daily meteorological processes, such as the nocturnal elevated foehn identified in this study. A very recent study (Xu et al., 2026) indicated that ground-based foehns on the eastern Taihang Mountains preferentially occur under stable atmospheric stratification, with a surface high over the windward side and a low over the leeward side, together with an upper-level cold trough at 500 hPa and pronounced subsidence at 850 hPa on the leeward side on the eastern foothills of the Taihang Mountains. However, this study did not extend its findings to the field of air pollution, nor did it clarify whether the aforementioned synoptic conditions are also conducive to the occurrence of elevated foehn. Overall, a better coupling of synoptic-scale circulation patterns and local-scale elevated foehn processes will further deepen our understanding of meteorological mechanisms underlying O<sub>3</sub> pollution”.

**Lines: 511-521.**