

Reply to Reviewer #2:

General comments

The authors have surely made efforts to improve and restructure the work. However, the revised paper still is a bit chaotic and confusing. As an example, the change of location for the two synthesis figures is not of big help in improving understanding, because they come now when the reader does not know anything about the results. Instead, maybe, a schematic presentation of the different usage of the numerous data sources could be more relevant and helpful in understanding the connections and logic. There are still interesting results presented in the Supplement and on which the results seem to be based.

Thank you for pointing out that the recent text structure can cause confusion to the reader. We now attempted to improve the understanding by introducing the concept and idea of the respective case study in the beginning of chapter 3 and 4. Schematic presentations (Figs. 1 and 6) are included, visually supporting the understanding of the analysis approaches. We have moved the two synthesis figures back to the end of the respective sections.

Trajectory Fig. S3a is now included as Fig. 4a as well to improve the understanding of the concept presented in Sect. 3/ Fig. 6. We decided to not include radio sounding profiles or synoptic maps in the manuscript, because the essential data is briefly written in the manuscripts. The new Figs. 1 and 6 should cover the gaps in understanding in respect to the synoptic scale data.

We now have included the previous Fig. S11 as Fig. 11 into section 4.3.

Specific comments

Lines 77-79: This sentence contains two “While”, which makes it not clear. In addition, it is not clear the meaning of “chemical markers”

The sentence was rephrased: *“Model data that provide large data sets of trace matter and meteorological data lack the high spatial resolution in the planetary boundary layer (PBL, Lochbihler et al., 2021), while altitude-resolved in-situ measurements by radio sounding or drones with high spatial resolution are usually limited to only a few measured variables, complicating investigation of rain front influences on the air mass’ chemical composition.”*

Line 84: You previously used BL, now PBL, please be consistent.

The acronym “BL” in the abstract was changed to “PBL” for consistency. Consequentially, minor changes in the abstract were needed to avoid exceeding the word count.

Lines 141-145: The trajectories are not coarse, it is the resolution of the meteorological model used to calculate HySplit trajectories that is coarse. The limitation of using this coarse resolution in complex terrain is never mentioned.

Both aspects have been considered in the revised version: *“For HySplit trajectories, which are based on coarsely resolved 0.25°-GFS analysis data and a low-resolution topography, complex terrain poses a substantial challenge. Therefore, ICON-D2 analysis and hourly forecast data were utilized for the gaps between the analysis time events (3 hourly) to calculate corresponding MLHs and backward trajectories within the German domain and to validate the HySplit trajectories (Figs. S3 and S4).”*

Line 174: The case study does not combine anything. Revise.

The sentence was revised as suggested: *“Our first case study took place at 20 June 2024 at the Spielberg site. Information on the synoptic conditions (Sect. 3.1), from local ground-based turbulence measurements (Sect. 3.2) and from drone-based measurements were combined to characterize different air masses (Sect. 3.3) to reveal how strong stratification can suppress turbulence and further extension of the CBL until the afternoon.”*

Figure 1 and 5 provide a synthesis of the different dynamical and chemical processes in the first and second cases, which is not possible to understand at the place where Figure 1 is mentioned (before the results).

The places where these Figures were mentioned and located were changed in the revised version of the text. See also the text at the major comment section above.

Lines 299-301: Can this be related to advection of aged air masses loaded with secondary pollutants (such as O₃ and secondary aerosol particles)? Could you explain this better?

We did not find a relationship between O₃ or the O/C ratio to most of various other secondary pollutant variables that would indicate advection of aged air masses. We investigated a relationship of O₃ and the particle O/C ratio with PM₁, PM_{2.5}, black carbon, pSO₄²⁻ and a change in the wind direction.

We improved the explanation: *“Advection of aged-air masses is also a potential explanation for enhanced O/C ratios as a correlation was found between the O/C ratio and particulate sulphate concentrations ($r = 0.83$), indicating aged air masses, although low correlation of O/C ratio with PM_{1/2.5} ($r_{PM1} = -0.26$, $r_{PM2.5} = -0.20$) does not necessarily support this. Backward trajectories do not indicate a specific source region for sulphur compounds and rather mixed air masses. Nevertheless, the strong correlation of O₃ with aerosol aging and the observed stratification pattern indicates that a delayed and suppressed extension of a young CBL can also lead to a delay in the onset of daytime chemistry.”*

Figure 4: What do you mean by “... after to before...”?

The figure caption was revised to: *“Figure 4: The ratios of the O₃ mixing ratio (top) and the particle number concentrations PNC (bottom) measured at five different times after the rain to those measured before the rainfall (at 11:00) were calculated for different altitude increments (color-scale).”*

Line 333: add “,” after “site”

“,” was added after “site”.

Lines 356-357: Rephrase: “24 h-backward HySplit trajectories...”

The sentence was rephrased according to the suggestion.

Line 357: The citation of Stein et al. (2015) is not relevant here, probably better for the methodology section.

The citation was removed at this location. Stein et al. (2015) is already cited in the methodology section.

Line 373: remove “,” after “2023”

The comma was removed after “2023”.

Lines 383-385: The sentence is not clear, rephrase.

The sentence was rephrased: *“After the first rainfall event (0.5 mm in 15 min), a remnant of the NBL still remains up to 200 m in agreement with the MLH predicted by ICON. Associated with the rain event,*

an increase of Ri and $d\theta_{eq}/dz$ indicates increased stability of air mass l above the NBL remnant. Evaporating precipitation, i.e., latent heat flux can act as an energy sink for sensible heat, which would otherwise enhance convective turbulence.”

Figure 7: What do you mean by “Development”?

We replaced “Development” with “Temporal evolution” to make clearer what is meant.

Lines 484: This acronym was already found elsewhere (possibly not consistently as said previously) so you do not need to redefine it here.

This acronym has not been found elsewhere in the revised version 1 (neither in the text nor in figure captions) and is first-time introduced in this line in the manuscripts. We want to clearly differentiate between the term “mixing layer height (MLH)” and “planetary boundary layer height (PBLH)”, since a mixing layer can be used as a synonym for the planetary boundary layer, but can also describe other atmospheric layers that might be separated by weak inversions layers. We have explained this in the beginning of Sect. 4.4:

“Until this point of the study the MLH is used as a synonym for the height of the planetary boundary layer (PBLH), which is considered the most relevant measure separating the free troposphere and the ground-influenced layer with different dynamical characteristics and composition (Stull, 1988; Tignat-Perrier et al., 2020; Kotthaus et al., 2023). Note that other kinds of stratification occur regularly in the troposphere (even in the planetary boundary layer) and are often not predictable, due to local topography, emissions, and heat reservoirs.”

Lines 540-550: You do not need to restate the gaps and introduction here.

We included this information in the Summary Section at the publisher’s request and do not see, any harm in leaving it there.

Line 571: Figure 41 is Figure 1?

Indeed, here, Figure 1 is referred to. This is actually what the WORD text reflects. The “4” is written in “strike through” mode, however, this is almost invisible in the pdf.

Lines 581-587: The future lines of research are not clear in terms of general lines and possibility to extend the current work. Please revise.

We revised the outlook: *“Future studies based on the presented observations should include field studies with a) vertically resolved NO and BVOC measurements above grassland to understand rain-triggered O₃ depletion and b) a focus on the influence of more complex terrains/surfaces on pre- and postfrontal dynamics and the postfrontal recovery of the PBL structure.”*

Figures S3 and S4: What do the colors of the lines stand for?

Explanations of the colored lines were included in the figures’ captions in the revised version of the Supplement.

Figure S11: Can you compare these concentration changes with measurement error? Not sure the figure is all clear.

We added the propagated measurement uncertainties to the numbers of the changes of O₃ and included a new axis highlighting the O₃-levels in the lowest bin which were used to determine the O₃

differences before and after rain. The uncertainties do not change the interpretation as they are relatively small compared to the O₃ differences across the rain events.

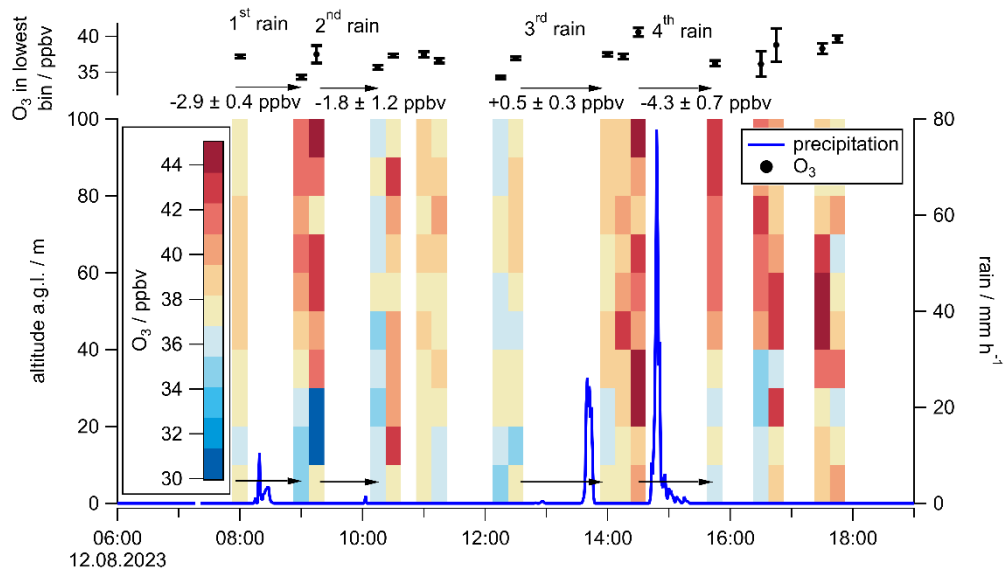


Figure 11: The vertically resolved O₃-time series (15 minute-time increments with 5 m altitude resolution, color-coded, measured with FLab) shows a decrease of 3.0 ± 1.3 ppbv O₃ at the lowest bin (top panel) after rain events (blue, 60 s data) and a slow increase as O₃-rich air is injected from higher levels.