REVIEWER#2

General comments

The authors introduce a new algorithm to identify aerosol types from the measurements of the new Vaisala CL61 ceilometer with depolarisation capabilities automatically and in near real-time. The algorithm CONIOPOL is described in detail how the use of the backscatter profile, the depolarisation, and the cloud base height, by filtering, smoothing, and a threshold-based classification and clustering method is combined to allow the monitoring of aerosol and clouds and their seasonal variability.

The algorithm design and the necessary procedures as calibration procedures are described and verified using measurements from a one-year record in 2024-2025 of the CL61 instrument at Uccle, a long-running, well recognised atmospheric monitoring station in Belgium. The algorithm is able to distinguish a wide range of aerosol types, such as ash dust, mix aerosol, ice crystals, classifies hygroscopic aerosols, and detects different precipitation states.

This manuscript is well organised and offers a valuable contribution to the use of automatic classification of aerosol by adding the depolarisation ratio for networks of low-cost instruments as E-Profile and should be published after addressing the suggestions below.

We sincerely thank the reviewer for the careful evaluation of our manuscript and for the positive assessment of our work. We greatly appreciate the recognition of the scientific value of CONIOPOL and its potential for the automatic near-real-time classification of aerosols and clouds using polarization measurements from the CL61. We are particularly grateful for your acknowledgement of the detailed description of the algorithm, its verification using a one-year dataset, and its potential applicability to operational networks such as E-PROFILE. Your constructive suggestions have helped us improve the clarity, accuracy, and overall quality of the manuscript. We have carefully considered each comment and revised the manuscript accordingly.

Before addressing the individual comments, we would like to summarize the principal modifications made to the manuscript following the reviewers' suggestions:

- The manuscript has been substantially revised to better **highlight** the role of the **cloud-phase and precipitation classifications,** which are now more clearly presented as an integral component of CONIOPOL rather than as a secondary extension of the aerosol classification.

- The **title** has been **revised** to better reflect the full scope of CONIOPOL by explicitly referring to both **aerosols and hydrometeors**. This modification better represents the capabilities of the algorithm and is consistent with the strengthened presentation of the cloud-phase and precipitation classifications throughout the manuscript.

- The **classification methodology** has been refined by introducing explicit **transitional classes** for aerosols, cloud phase, and precipitation. These intermediate categories provide a more physically realistic representation of observations exhibiting mixed optical characteristics and reduce potential misclassification arising from overlapping depolarization signatures.
- The justification of the depolarization thresholds has been substantially expanded. The selection of the **depolarization thresholds** is now supported by a more comprehensive **review of the peer-reviewed literature**, including recent studies using polarization lidars at wavelengths comparable to the CL61, providing a stronger physical basis for the adopted classification scheme.

- The **CAMS comparison** with CONIOPOL has been substantially **revised**. The analysis is now performed on a **seasonal basis, extended vertically up to 10 km**, and complemented by a more detailed discussion of the physical interpretation, **statistical significance**, and **limitations of the comparison**.

- During the implementation of the newly introduced transitional classes, we identified an error in the classification mask affecting the **Smoke/Marine aerosol** category. In the previous version, this category was only considered when no cloud was detected. Consequently, Smoke/Marine aerosols located beneath or within cloudy conditions were inadvertently excluded from the statistics. This issue has now been corrected, resulting in a substantially higher occurrence of the Smoke/Marine category and a markedly improved correspondence with the CAMS aerosol fields.

- We also revised the treatment of **weakly depolarizing targets under cloudy conditions**. In the previous version, low-depolarization observations within clouds were systematically assigned to the Fog/Drizzle/Mist category, even when they were clearly disconnected from the surface. This **decision-tree branch has been removed**, leading to a more physically consistent classification and an increased occurrence of the Liquid Cloud (Droplet) category.

- To avoid ambiguity in the interpretation of weakly depolarizing aerosols, the **former "Hygroscopic Aerosol" category** has been **renamed "Continental Aerosol"**. This terminology more accurately reflects the physical nature of the classified particles and avoids confusion with the Smoke/Marine category, since both aerosol types are hygroscopic but are associated with distinct atmospheric environments. The revised discussion further demonstrates that these two categories exhibit different vertical occurrence profiles, consistent with their association with the continental and marine boundary layers, respectively.

- The presentation of the **normalized cumulative occurrence profiles** has also been **revised**. Instead of displaying monthly statistics, the revised manuscript now presents **seasonal occurrence profiles up to 15km**, providing a clearer representation of the dominant atmospheric regimes while improving consistency with the revised CAMS intercomparison, which is now analysed seasonally and extended vertically up to 10 km.

- The **showcase figure** has also been **updated**. During the revision process, **several display issues** were identified in the previous version (e.g. the omission of a secondary cloud layer in the graphical representation). These issues only affected the visualization and **did not affect the**

CONIOPOL classification itself or any of the statistical analyses, which were produced directly from the classified data.

Specific comments:

The LDR is defines several times in the introduction for linear depolarisation ratio. In one case it is also used for volume depolarisation ratio (line 155) and in one case for particle linear depolarization ratio (line 585). Please clarify what is used in the algorithm.

We thank the reviewer for this comment. We have revised the Introduction to explicitly distinguish between the volume linear depolarization ratio (VDR) and the particulate linear depolarization ratio (PDR), and to clarify their respective physical meanings. To avoid misleading the reader, the term volume linear depolarization ratio (VDR) is now explicitly used whenever referring to depolarization measurements, and this terminology is consistently adopted throughout the remainder of the manuscript and in the abstract.

Fig. 8: and paragraph 6.1.1.: It is unclear what is meant by occurrence, if it can exceed 100%? 5% occurrence means 5% of all observed categories? During which time frame?

We thank the reviewer for this comment. The monthly occurrence definition has been clarified in the revised manuscript to avoid ambiguity.

For each category, the monthly occurrence is calculated as the percentage of hourly periods in which the corresponding category is detected in at least 60% of the available observations within that hour, relative to the total number of hourly periods available during the month. Multiple categories may coexist within the same hourly period because different aerosol and hydrometeor types can occur simultaneously at different altitudes. Consequently, category occurrences are not mutually exclusive and their sum may exceed 100%.

Fig. 9: The text of the axes and captions should be readable without turning around the graphs.

Done in the revised manuscript.

Line 460 – 467: Intercomparison with CAMS: please explain in more detail how the CAMS values are assessed conditionally on CONIOPOL detections in both time and altitude, and why this leads to multiple use of the CAMS values.

We thank the reviewer for pointing out that the original description of the CAMS comparison was insufficiently detailed. Following this comment, the methodology has been completely revised and rewritten.

The revised manuscript now provides a detailed description of both the temporal and vertical matching procedures. Since CAMS aerosol profiles are available every 3 h, the corresponding CONIOPOL observations are aggregated over the same 3 h interval. This interval is divided into three consecutive 1 h periods, and a CAMS profile is associated with a given aerosol category only when the category is detected during at least 60 % of the available CONIOPOL observations in at least two of the three hourly periods. This persistence criterion ensures that only persistent aerosol layers are retained for the comparison.

The vertical comparison has also been substantially improved. Instead of considering only two broad altitude ranges as in the original manuscript, the revised analysis is now performed throughout the atmospheric column up to 10 km using successive 250 m altitude intervals. This provides a much more detailed characterization of the vertical relationships between CONIOPOL classifications and CAMS aerosol fields.

The sentence referring to the "multiple use" of CAMS values has been removed, as it no longer reflects the revised methodology. The updated manuscript now describes the comparison procedure unambiguously and explains the statistical analysis performed within each altitude interval.

Fig. 10 and 11: Please explain more clearly, how these box plots show a good or bad agreement between CAMS and CONIOPOL results. It is not that obvious.

Figures 10 and 11 have been replaced by a more detailed altitude-resolved analysis.