The authors demonstrate that the additional information of the fluorescence backscatter coefficient improves hygroscopic growth studies with lidar by presenting two case studies. This technical improvement advances the possibilities to study hygroscopic growth of aerosol particles with lidar, which is an important topic for ongoing and future research. Besides this primary goal of the manuscript, a new aerosol clustering method is introduced. Here, I see some difficulties which are further elaborated below. These difficulties lead to my decision to accept the manuscript after major revisions.

Major comments:

The introduction of the new aerosol clustering method FLARE-GMM is a topic on its own and is somehow hidden in the current manuscript. It is neither mentioned in the title nor in the abstract (except of a short hint on line 13). No one will find the method later on, because from the title and abstract a hygroscopic growth study is anticipated.

My decision is to remove the description of FLARE-GMM from the manuscript and focus on the hygroscopic growth study. FLARE-GMM might be presented in an own dedicated publication.

Thank you very much for your comment. We agree with this decision, we removed the description of FLARE-GMM from the manuscript, and focused on hygroscopic growth study.

These are the reasons which led to my decision:

I. There are no compelling reasons why you need FLARE-GMM for your two case studies. You use it to assess the aerosol type, urban and smoke, respectively. This assessment can be done with conventional lidar-based aerosol typing schemes based on intensive optical properties or with the additional use of the fluorescence capacity as described in Veselovskii et al., 2022.

II. At the current state, the presentation of FLARE-GMM algorithm seems not mature yet.

1. Firstly, it seems to be only applicable to the atmospheric conditions at Lille and it is therefore not easily transferrable to other locations. Especially, the absence of marine aerosol in your clustering approach limits it to continental sides. Globally, marine aerosol is one of the major aerosol components. Probably, a clustering has to be repeated for each measurement station.

2. Secondly, you state in your conclusion that FLARE-GMM will be enhanced by adding multiwavelength depolarization ratios, lidar ratios and the Ångström exponent. It would be good to add these quantities and prepare a dedicated publication about the mature FLARE-GMM method.

3. The description of the method is presently rather short and could be extended in an own publication. It is not clear to me whether the uncertainties of the input quantities are considered and how do you train the algorithm, e.g., which number of data points you have used. Furthermore, you could explain how RH is considered in the model.

4. And lastly, the classification accuracy estimation (Sect. 3.1) in the presented way is not so convincing:

   o You state that Figure 4 contains dust examples and Figure 5 a smoke layer. Except for the airmass origin you don't mention any other proof that it is the case. Intensive optical properties can be easily used to proof the presence of dust or smoke layers, respectively.

   o The comparison via the confusion matrix with the NATALI algorithm gives an indication that these algorithms provide similar results. However, it is not a convincing proof. Especially, the inability of NATALI to detect any dust layers arouses concerns. I would recommend to compare it more than one aerosol classification scheme. The well-established schemes of Burton et al., 2012 or Groß et al., 2013 might help to dispel some doubts.

Minor comments:

- The title highlights the microwave radiometer, but in your manuscript, it is not very prominent. Please highlight the use of the radiometer stronger in your text

  Part 2.1 of the article has been developed to highlight more the role of the radiometer.

- Affiliations: The level of detail varies a lot between affiliation 1 and 3.

  More details have been added on affiliation 3

- L 29: Please use the term "ice nucleating particle (INP)" according to the conventions presented in Vali et al., 2015 (needs not to be cited, just for your information).

  Correction made

- L 38: You mention a range of instruments and then directly switch to lidar systems. Traditionally, hygroscopic growth was studied with nephelometers. Please add some lines and references about other studies of hygroscopic growth.

  The nephelometer has been mentioned and other studies using this method have been mentioned

- In general, the reference list concerning hygroscopic growth studies is rather short. Please consider work, e.g., by Paul Zieger, Gloria Titos, Sebastian Düsing and others. Mostly, extinction enhancement was studied, but there are further lidar studies about the backscatter enhancement factor.

  More reference on hygroscopic growth study have been added

- Be more precise in your formulations, e.g.,

  L 50 approximately 460 nm -> please provide the central wavelength and the width of the interference filter, here and in line 71

  Change made: central wavelength 466nm, width of 44nm

  L178 What do you mean with notable temporal resolution? Be precise.

L248 from model estimations. From which model? Probably also from ERA-5, but it is nowhere mentioned.

Precision added in the text, indeed the model mentioned is ERA-5, but the general idea is to express the fact that it is not estimated by a direct measurement of an instrument.

L250 remains highly stable -> How do you define "highly stable"? I would not consider the curve in Fig. 7 to be highly stable.

Remark taken into account, the objective here is to look at the fluorescence and rather than looking for stable behavior, instead make sure that the variations are not too important which would potentially mean that there is a change in the air mass of the considered layer (there is no strict criteria but as long as the ratio std/mean is lower than 0.5 on the layer, we consider that the case is suitable to study hygroscopicity)

- L 36,37 Why the references include a a letter for the surname?

  Mistake corrected

- L 46-49: Too much information for an introduction.

  Remark taken into account, the passage has been shortened

- L 52 like **pollen** or biomass burning **smoke**

  Correction made

- L 70 At which wavelengths the depolarization ratio is measured?

  532nm, added in the text

- L 71 particle linear depolarization ratio

  Correction made

- Indices should not be in italic, e.g., beta_fluo . Please correct in the text, the equations and figures.

  Correction made

- L 90 The link is not necessary.

  Has been removed

- Fig. 1 + 2: What is the purpose of these figures? They are not needed to understand the manuscript. Especially, Fig. 2 is just showing a commercially available instrument.

  We agree with you and the figures has been removed

- L 108/109 The assumption that the fluorescence backscatter is unchanged by hygroscopic growth is quite fundamental for your study. Therefore, I would recommend to elaborate a bit further on this assumption. You could summarize/repeat the main arguments of Veselovskii et al., 2020 here again.

  More precision has been added to the text, repeating the argument stated in Veselovskii et al., 2020

- L 130 Here, the absence of marine aerosol puzzled me (see comment above). It is characterized by its strong hygroscopic growth and change in depolarization ratio with RH as shown in previous lidar studies.

  Passage removed from the article

- L 163: "absence of definitive benchmarks" -> Wouldn't be manual typing based on the intensive properties such a definitive bemchmark? -> maybe use depolarization ratio, lidar ratio, Angstrom + fluorescence capacity to do the typing?

  Passage removed from the article

- L 166 unequivocally -> You provide only backward trajectories and no further proof.

  Passage removed from the article

- Often, you introduce the figures twice, once above the figure and once below (e.g., Fig 6, 8, 9). In the manuscript, you can place the figure in between, but in the real paper the figure will be placed somewhere else. E.g., L 209/210 contain the same content as L 214.

  Remark taken into account, the figures are now introduced only once

- Fig. 6 Please explain how do you get from 38 profiles to 4262 data points.

  Passage removed from the article

- L 219 Marine/CC -> What does it mean?

  Passage removed from the article

- Please keep the same date format, e.g., 29 July 2021. At some instances you switch the American format.

  Correction made

- Please use an appropriate time format, e.g., 22:00 instead of 10 pm.

  Correction made

- Fig. 7 and following: You state that your profile was measured at 10 pm. But how long was your measurement? From 22:00 to 22:01 or to 23:00 or from 21:30 till 22:30? Be more precise.

- Fig. 7 and following: Do you report the altitude about ground or above sea level?

- Fig. 7 and following: You state LILAS retrieved optical properties. But do you retrieve the potential temperature from the lidar? Be more precise.

- Fig. 7 and following: In the caption you should write the whole name of the property and not just the symbol, e.g., beta_532, because the caption should explain the figure. If you just repeat what is stated on the axis of the figure, there isn't any additional information. It holds especially for Fig. 11.

- Do not change the number of significant digits, e.g., L 264 0.91, L 313, and Fig. 11b.

- L 299 The potential temperature is monotonically decreasing in the indicated height range. How do you define a stable potential temperature? The best would be to define it at some point.

- L 315 The uncertainty just increases from 0.28 to 0.3, meaning that the uncertainty was high even without considering the fluorescence backscatter.

- L 320 What do you mean with a decrease in RH by 10%? The statement is ambiguous, because it can mean a decrease from 78% to 68% or 10% from the actual value. I guess, you mean the first one.

- L 355 an urban aerosol layer

- L 359 Could you move LILAS to a place where radiosondes are launched? Or could you use data from a different lidar station with available radiosondes?

That would be great but LILAS is a big instrument, it can be moved but not easily and many people work on this instrument. We did not have opportunities to move it to a place where radiosoundings are performed. Unfortunately, there is no lidar station that I know of which have both a fluorescence channel on its lidar, and the ability to launch radiosoundings