We thank the reviewer for his constructive comments. We believe the comments helped us to improve the overall quality of the manuscript. Please find below our answers to the comments, with indication of the changes made in the revised manuscript. For clarity, we also include the original reviewer's comments in **bold**.

Manuscript : **"A new approach to the crystal habit retrieval from far infrared spectral radiance measurements"** , Di Natale et al. 2023

This paper presents an inversion algorithm for retrieving the shapes of ice cloud particles using far infrared spectral radiance measurements. The algorithm's performance is evaluated using simulated measurements from the new far infrared sensor, Far-infrared Outgoing Radiation Understanding and Monitoring (FORUM), in various scenarios: tropics, mid-latitudes, and polar regions. This study is a continuation of a previous paper by Di Natale and Palchetti (2022) that focuses on the algorithm's development and validation.
Overall, the results indicate a successful convergence of the inversion algorithm in tropical and mid-latitude scenarios. However, some challenges were encountered in the polar scenario, particularly when considering retrieval affected by FORUM measurement noise. Notably, there were significant differences in the simulated outgoing longwave radiation when using pre-defined fixed shapes compared to retrieved shapes. These findings have implications for improving ice cloud parameterization and enhancing our understanding of ice particle habits in different locations.

While the paper is logically structured and well-organized, I have a few suggestions to enhance its clarity:

1.Figure 1: Why does the difference between the radiance computed with the rigorous approach and the approximation increase with OD before OD < 2.0 but decrease when OD > 2.0? The author should provide an explanation for this trend.

In the revised version of the paper, we replaced Fig. 1 with a simpler and more informative version. The revised Figure 1 is made of two panels (a) and (b), referring to the computations made with L_m=200μm and L_m=40μm, respectively. Each panel shows the radiance differences obtained for several values of OD, spanning a broad range, from 0.001 to 150.
Explaining the behavior of these differences on the basis of the radiative transfer equation and of the expressions used to compute the various contributing elements (see Di Natale et al. 2020) is a very complicated issue. Despite of this complication, we see that the asymptotic behavior of the differences, for OD $\rightarrow$ 0 and for OD $\rightarrow$ ∞ is reasonable. Specifically, for OD $\rightarrow$ 0, i.e. for ice amounts getting closer and closer to zero, the cloud effect on the upwelling spectral radiance must get closer and closer to zero, thus the two compared methods should provide the same result, as confirmed by the lines of Fig. 1 corresponding to the smallest OD values. Conversely, in the presence of a very opaque cloud (OD>>1), the radiance should depend uniquely on the absorption and scattering processes occurring at the cloud top. Therefore, we expect the differences between the radiance predicted by the two methods to approach a wavenumber - dependent asymptotic value that does not change for any further increase of cloud OD. This behavior is actually confirmed looking at the lines of Fig. 1 that correspond to OD ≥ 30, they almost overlap. Note that the differences between the two methods increase for increasing OD, reach a maximum amplitude for OD ~ 2, then decrease to their asymptotic value achieved for OD >> 1.
In Sect. 2.4 of the revised paper, we included this explanation of the asymptotic behaviors of the observed differences between the two methods compared.

2. Section 2: I am wondering which database of the optical properties of ice crystals was used in this study. Yang et al. (2013) was continuously updated based on the improvement of computational techniques. For example, Bi and Yang (2017) updated the database based on the invariant imbedding T-matrix method (Bi and Yang, 2014) and improved ray tracing technique for absorbing particles.

We are aware about the latest release of the single scattering properties databases by Bi and Yang (2017), however, we preferred to use the databases of Ping Yang et al. (2013) to allow for the intercomparability of this new rigorous approach presented, with the approximated method of Di Natale and Palchetti, (2022). For the present work this choice does not represent a limitation as we are dealing only with simulated measurements. We fully agree, however, that for the analysis of real measurements we will have to use the most recent release of the single scattering properties databases. However, we added the reference mentioned by the reviewer in the text at line 116.

In the revised manuscript, we added a statement to justify our choice. Again, the statement was added in Sect. 2.4.

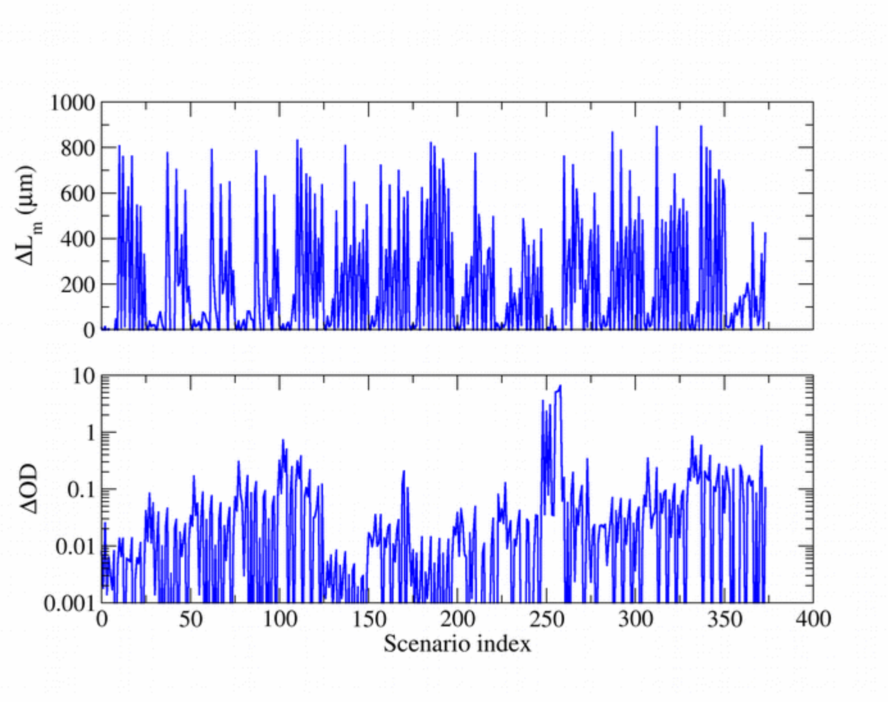
3. Section 5, Lines 399-410: The author conducted test retrievals using the predefined habits of King et al. 2004 and the retrieved habits in this study, assuming that the atmospheric, surface, and cloud parameters were known. However, if the cloud parameters were also influenced by the habits in the retrieval when considering simultaneous retrieval of cloud parameters, I wonder if the value of 2.7 W/ would be lower. Additionally, it is possible that the difference caused by the habits would be partially compensated by adjusting the cloud parameters.

Probably this part was not clear in the original manuscript. In the revised manuscript, we rephrased the related paragraph in Sect. 5, to better explain results of the test we carried out.

Starting from the synthetic measurements generated for the analysis presented in Sect. 3.3, here we carry out the retrieval of cloud parameters (OD and L_m) with two different approaches: in the first case (a) we assume the particle habit distribution to be known and equal to the distribution of King et al. 2004. In the second case (b), along with OD and L_m, we also retrieve the habit fractions p_1, …, p_4 introduced in Sect. 2.1. In both cases (a) and (b), the atmospheric and surface states as well as the cloud top are assumed as exactly known.
In figure 8, we finally compare the OLR fluxes computed from the atmospheric and cloud states obtained at the end of the retrievals (a) and (b), to the fluxes obtained from the "true" atmospheric and cloud states assumed for the generation of the synthetic measurements.

In conclusion, we agree that the retrieval may use cloud parameters, such as OD and L_m, to compensate for an eventually erroneous assumption of the ice particle distribution, however this compensation is actually free to happen also in our retrievals of case (a). Thus, the possible reduction of the flux error by compensation with the retrieved cloud parameters is already included in the results presented in figure 8. From the figure it is clear that, the compensation effect reduces only partially the flux error as this latter is still larger for case (a) than for case (b). The two panels in the figure below show the differences between cloud parameters OD and L_m retrieved in the cases (a) and (b), highlighting the amplitude of the systematic compensation effect mentioned above. For

brevity, we decided for not including these figures in the revised paper, however in the revised paper we expanded the discussion of the results.
Note that, in principle, when retrieved simultaneously, also the parameters relating to temperature or water vapor vertical profiles or to surface temperature or surface spectral emissivity could compensate for an erroneous cloud ice size distribution assumption. The effectiveness of this type of compensations in reducing the OLR flux error, however, is expected to be much lower as compared to that of cloud parameters. This is because the spectral fingerprints of atmospheric and surface parameters have a shape substantially different from that due to cloud parameters.



4.In Figure 1, the y-axis tick labels of "0,001" should be "0.001". This typo also exists in Figures 4, 6, 7, and 8.

Corrected.

5.Line 278: "the a priori..." should be corrected.

Corrected.

6.Line 324: "...a part 4 out..." should be corrected.

Corrected.

7.Line 319: "Fig.s 3 and 4..." should be corrected.

Corrected.

8.Line 410: “(0.6+-0.4)W/m^2 Wild et al. (2013)” should be corrected.

Corrected.

References:

Di Natale, G., & Palchetti, L. (2022). Sensitivity studies toward the retrieval of ice crystal habit distributions inside cirrus clouds from upwelling far infrared spectral radiance observations. Journal of Quantitative Spectroscopy and Radiative Transfer, 282, 108120. https://doi.org/10.1016/j.jqsrt.2022.108120

Bi, L., P. Yang, (2017). Improved ice particle optical property simulations in the ultraviolet to far-infrared regime. Journal of Quantitative Spectroscopy and Radiative Transfer, 189, 228-237. https://doi.org/10.1016/j.jqsrt.2016.12.007

Bi, L., P. Yang (2014). Accurate simulation of the optical properties of atmospheric ice crystals with invariant imbedding T-matrix method. Journal of Quantitative Spectroscopy and Radiative Transfer, 138,17-35. https://doi.org/10.1016/j.jqsrt.2014.01.013

King MD, Platnick S, Yang P, Arnold GT, Gray MA, Riedi JC, et al. Remote sensing of liquid water and ice cloud optical thickness and effective radius in the arctic: application of airborne multispectral MAS data. J Atmos Oceanic Technol 2004; 21:857–75. doi: https://doi.org/10.1175/1520-0426(2004)021<0857:RSOLWA>2.0.CO;2

Di Natale, G., Palchetti, L., Bianchini, G., and Ridolfi, M.: The two-stream δ-Eddington approximation to simulate the far infrared Earth spectrum for the simultaneous atmospheric and cloud retrieval, Journal of Quantitative Spectroscopy and Radiative Transfer, 246, 106 927, https://doi.org/10.1016/j.jqsrt.2020.106927 , 2020.