RC3

This study aims to find optical models for small ice crystals identified as frozen drops or frozen drops aggregates. Several optical models are compared to data obtained during the CIRCLE-2 campaign. The manuscript is well written and the topic is of interest for ACP. However, I have several questions that should be addressed before I would recommend publication.

We sincerely thank the reviewer for the careful reading of the manuscript and the many helpful and constructive suggestions that have improved the quality of the manuscript substantially.

In response to the reviewers' comments, we have revised the manuscript, with the major modifications outlined as follows. First, we extended the calculations by increasing the distortion parameter (t) to a maximum of 0.95 in increments of 0.05, resulting in changes to Sections 4.1, 4.2, and 4.3. The analysis of these extended results has been incorporated into the revised manuscript. Additionally, as the reviewers pointed out, to avoid redundancy with Section 4.1, we have removed Sections 4.2.1 and 4.2.2, which compared results for homogeneous component aggregates represented by Gaussian random spheres or droxtals, from the main text and included them in the Supplement (S1 and S2). Another significant modification is the introduction of an additional criterion: the number of angles (ω) falling within the ±20% uncertainty range of PN, which was added to assess the accuracy of our theoretical calculations against observational data. Further discussion on ω has been integrated into the revised manuscript. Lastly, we modified the method used to construct habit mixture models, as explained in Section 4.3, and the corresponding comparison results are now thoroughly discussed in that section. Although significant revisions have been made in this study, the core results presented in the original submission remain unchanged, demonstrating the robustness of our findings.

- The observations are an important part of this paper but they are hardly described at all. More details need to added. Specific questions are:
  1. What does the PN measure and how?
  2. Are these single crystal or bulk observations?
  3. What selection of data is made? Are there only FD or FDA's in this sample?
  4. What do the grey ranges in figure 5 and others mean? Are the spikes seen in these ranges real features or more like noise?
  5. How can we interpret the mean of the observations that is used as a target?

To better interpret PN measurements and remove ambiguity, we depict only the PN-measured average P_{11} (i.e., black filled circles) of frozen droplet aggregates, as presented in Gayet et al.

(2012) and Baran et al. (2012), in the new figures of this manuscript. The gray-shaded areas shown in the original figures, representing the full range of P_{11} measurements obtained during the entire CIRCLE-2 campaign, have been removed in the new figures. Additional detailed information about PN measurements has been added.

At the beginning of Section 4, the following sentences have been included:

"The PN, as detailed by Gayet et al. (1997), is an airborne instrument designed to measure the angular scattering pattern, or scattering phase function, of an ensemble of cloud particles ranging from a few micrometers to about 1 mm in diameter. Operating at a wavelength of 0.8 μm, the PN captures scattering angles between ±15° and ±162° with a resolution of 3.5°, typically providing data at 32 distinct angles from among 56 photodiodes (Jourdan et al., 2010). Measurements at near-forward and backward angles (θ < 15° and θ > 162°) are less reliable due to diffraction effects caused by the edges of holes drilled in the paraboloidal mirror (Gayet et al., 1997). To ensure continuous sampling, the PN integrates the signals from each photodiode over periods selectable by the operator, commonly around 100 ms. The average measurement errors for the angular scattering coefficients range from 3% to 5% for angles between 15° and 162°, with a maximum error reaching 20% at the outermost angles (Shcherbakov et al., 2006). The instrument's ability to directly measure the scattering phase function allows for differentiation of particle types and calculation of essential optical parameters, such as the extinction coefficient and g. Gayet et al. (2002) reported an uncertainty of 25% for the PN-derived extinction coefficient, while the estimated absolute error for the g ranges from ±0.04 to ±0.05, depending on the prevalence of large ice crystals within the cloud (Jourdan et al., 2010).".

At the beginning of Section 4.1.1, the following sentence has been revised:

"Figure 5a illustrates the comparison between the P_{11} of 120 single FDs models, represented by Gaussian random spheres, and the PN measured average P_{11} (Baran et al., 2012; Gayet et al., 2012) obtained in the developed overshooting convective cell at 11,080 m altitude (T=−58 °C) at 13:08:15–13:08:40 UTC on 26 May, 2007 during CIRCLE−2 (i.e., black filled circles).".

Measurements of FD and FDAs were confirmed with CPI images during the CIRCLE-2 campaign. Gayet et al. (2012) stated, *"A visual classification roughly gives a proportion of 70 % of typical chains of ice crystals and ice particles exhibiting a faceted shape have been rarely observed."*. Because of this reason, we emphasize the need for coupled measurements of light angular intensity and image of the same particle in Section 5 – *"In this respect, it should be emphasized that the measurements of the intensities of scattered light across the full range of* *scattering angles, coupled with images of ice crystals are required. The use of an advanced cloud probe, such as a particle habit imaging and polar scattering probe (Abdelmonem et al., 2016; Schnaiter et al., 2018; Waitz et al., 2021), capable of capturing the detailed 3D morphologies of FDs or FDAs, is essential to further this understanding.".*

- Related to the last question about the data: Why is the mean of the observations an appropriate target of an optical model? Should the variation not be represented by a set of models? On line 598 it is stated that "the assumption that FDAs consist of homogeneous components was found to be inadequate for interpreting the in situ measured single-scattering properties." What is the criterion for calling these other models inadequate? They are close to the mean of the observations and within the grey range. So how well should any model fit the mean of the observations to be deemed an adequate model?

We fully agree with the reviewer's concerns regarding the natural variabilities of the optical properties of ice crystals. It is indeed challenging to mimic every detailed optical feature of natural ice crystals in ice clouds using idealized optical models. Many factors, such as size, shape, surface roughness, inclusions, and orientation, contribute to this variability. Additionally, there are observational uncertainties when measuring the optical properties of ice crystals.
The PN instrument, like other instruments, has inherent uncertainties, and the resulting measurements reflect these uncertainties. Despite these uncertainties, it is necessary to evaluate the accuracy of our theoretical calculations against observations. To do this, we need a specific criterion. In this study, we selected the root mean square error (RMSE) between the theoretical calculations and the PN-measured average P_{11} and newly introduced parameter, the number of angles (ω) falling within the ±20% uncertainty range of PN, as our criteria.

- The effect of distortion on the models is investigated. The best match is found for the highest distortion applied. Therefore, I suggest to also apply higher distortion values to show that the optimum is indeed at 0.3, or whether it is at a higher value. Also please indicate for which specific case of Gaussian random sphere and which specific droxtal type the distortion is applied. I also suggest adding an extra panel just as in Fig 6, 8, 11 and 14 showing the change in g as a function of t.

In response to the reviewer's comment, we have extended the calculations by increasing the distortion parameter t to a maximum of 0.95, and the analysis of these results has been included in the revised manuscript. We have also made additional revisions to specify the cases for the Gaussian random sphere and droxtal types where the distortion is applied. Furthermore, we have added an extra panel, as suggested, showing the change in g as a function of t in the revised manuscript.

- On line 603 you state that "the findings of this study have significant implications for improving the accuracy of simulations regarding the radiative impacts of deep convective clouds and associated anvils on the Earth's climate system". You did not show this. What is the basis for this statement? Often optical models with smooth phase functions and asymmetry parameters close to those you are finding are used in such calculations, so I would not expect a large impact. Please discuss a firm basis for this statement or remove or weaken this statement, also in the abstract.

The sentence on line 603, "*The findings of this study have significant implications for improving the accuracy of simulations regarding the radiative impacts of deep convective clouds and associated anvils on the Earth's climate system.*", has been replaced with, "*The findings of this study suggest potential implications for improving the accuracy of simulations regarding the radiative impacts of deep convective clouds and associated anvils on the Earth's climate system.*".

Additionally, the sentence in the abstract, "*The result of this study carries important implications for enhancing the calculation of single-scattering properties of DCCs.*", has been replaced with, "*The results of this study suggest potential implications for enhancing the calculation of single-scattering properties of ice crystals in DCCs.*".

- In the conclusions, the findings numbered 2, 3, 5, 6, 7, 8 are too detailed in my opinion and I suggest removing them.

Following the reviewers' comment, the number of significant findings stated in Section 5 Summary and Conclusions have been reduced without losing the importance of the findings.